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THE JOURNAL OF INTELLIGENT MACHINES

ROBOTICS AGE™

THE BEGINNING FOR PERSONAL ROBOTICS?

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ROBOTICS AGE™

AUGUST 1984 VOL. 6 NO. 8

EDITORIAL

FEATURES

DEPARTMENTS

About the cover: This month's reverie by Jonathan Graves depicts the dawning of the personal robotics age. The robot characters are fantasy extensions of several robots actually displayed at the Congress.

BPA Membership (SMA Division) Applied for, August 1983

JUNE TRAVELOGUE

Have you ever noticed that all the really interesting trade shows and conferences inevitably are scheduled at the same time? Months may go by without an interesting show and then suddenly it seems you are doing nothing but attending conferences. The first week in June was one such travel-packed week, which included the Consumer Electronics Show, Robots 8, and the 1984 Rochester Forth Applications Conference.

All three of the shows were interesting and left me with a serious case of information overload. Since this issue contains a separate description of the Robot 8 show by Walter Banks, I will concentrate on the highlights of the Consumer Electronics Show and the Rochester Forth Conference.

HELLO JR.

The Consumer Electronics Show brought with it the long-awaited introduction of Heath's second robot, HERO Jr. The newcomer is billed as being "the first affordable, personal robot with a dynamic personality." According to Heath, the HERO Jr. is a *companion* robot which requires no programming skills to operate. Jr. has a number of preprogrammed activities which shape its unique personality. It roams, explores, sings songs, recites poetry, and speaks English. The publicity photos show Jr. jogging with friends,

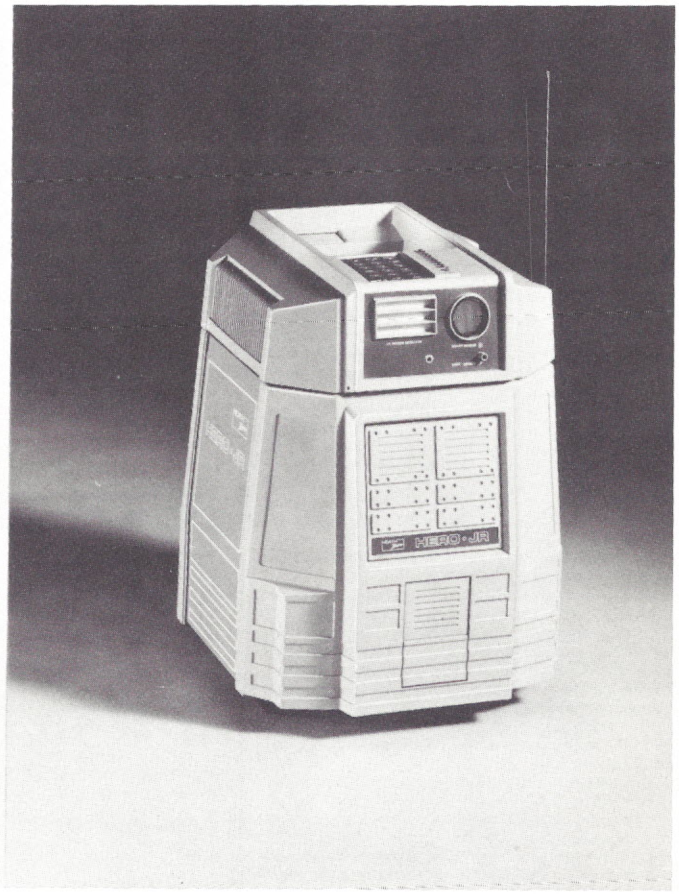

Photo 1. Two generations of Heath HEROs. The original HERO 1, shown on the left, is designed as a trainer to teach robotics in schools and industry. The new HERO Jr. has been designed by the Consumer Division to be a personal robot. It uses preprogrammed computer cartridges to perform a variety of entertaining and patrol functions.

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sitting at a bar, and entertaining an average family in their living room.

As shown in Photo 1, HERO Jr. looks similar to the HERO 1 robot. The major external differences are a nonrotating head, a slightly smaller size and the lack of an arm. The HERO 1's hexadecimal programming keyboard has been replaced by a 17-key *personality adjustment* keyboard. Jr.'s face is composed of an ultrasonic Polaroid™ sonar transceiver, a light sensor, and an optional infrared motion detector. Other transducers provide synthesized speech output and sound sensing. In a major improvement over the HERO 1, Heath has supplied an RS-232 communications port and a ROM-pack plug-in slot which accepts game-type programming modules.

The HERO Jr.'s motive system is reversed from the HERO 1. The HERO 1 used a triwheel platform with the forward wheel providing steering and motive power. Anyone who has worked with the HERO 1 has discovered that the front wheel is difficult to keep straight and that the slightest bump in the floor could drastically affect its position. The HERO Jr. has solved this problem by moving the single drive and steer wheel to the back, using it to push the two forward idler wheels. Although I was originally skeptical when I heard about this arrangement, the demonstration models showed that the design works quite well. Moving the single drive wheel to the back also provides HERO Jr. with extra traction when moving forward from a smooth floor onto a rug.

Another wheel base improvement has been made by moving the wheel turn counter from the power wheel to one of the idler wheels. When programming the HERO 1, it is often difficult to determine if the robot has been stopped on a slippery surface. The drive wheel often just sits and spins. Since the HERO Jr. monitors one of the idler wheels, it can immediately determine that power is being applied to the drive wheel but the robot is not moving.

All of HERO Jr.'s electronic controls have been condensed onto a single printed circuit board. Most of the Jr.'s interior is empty and provides plenty of room for adding new components. However, it appears that Heath has not supplied an opening for third party hardware vendors. When I asked several Heath representatives how the Jr. could be expanded with new hardware, they replied that the only way to access the address and data bus was from one of the read-only memory sockets. Although there seem to be several points where data and address lines may be available on the printed circuit board, I cannot be certain without further documentation.

To me, the apparent inability to add new hardware boards is a serious shortcoming. The explanation may come from the fact that the HERO Jr. has been introduced by the

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Heath Consumer division and not the Educational division that produced the HERO 1. As a consumer product, the Jr. could be assumed to stand alone and operate without the need for expansion capabilities. Indeed, in a break from all past Heath policies, the HERO Jr. is being marketed through "high-tech department stores and retailers that sell computer games and software." According to company literature, the Jr. will be sold to "General consumers, especially electronics and computer game enthusiasts and the type of consumer who buys a satellite receiver, a VCR with Hi-Fi, and compact disk audio." However, as a consumer toy, the Jr.'s $1000 price tag seems expensive.

Let me ask that perennial question, "What does it do?" The Jr. can run around the house, bumping into things and saying "Excuse me." It can act as a personal alarm clock and wake its owner at a predetermined time. It can seek out people with the optional infrared detector. It can also accost intruders and request authorization codes. Now, are these abilities worth $1000? The HERO 1, although more expensive, was aimed squarely at the educational and experimental market. When people ask what the HERO 1 does, the answer is simple: the HERO 1 *teaches*. I'm not so sure about the Jr.

Another comparison between the HERO 1 and the HERO Jr. is the amount of third party hardware and software support that the HERO 1 has received. HERO 1 came with a full set of schematics and documentation that let knowledgeable engineers add various peripherals. It appears that it will not be so simple to expand the HERO Jr. However, since Jr. has a ROM-pack cartridge on board, we may see much more software support than was available for the HERO 1. Heath does say that various development houses are working on additional software for the Jr. If these houses manage to develop some very interesting software, it may offset the inability to provide extensive hardware expansion. HERO Jr. may become a software-driven product rather than a hardware-driven one.

The real question in my mind comes down to price. If the Jr. is indeed intended as a "high-tech toy" then it appears to be too expensive. I would be much more likely to purchase a Jr. if it had expansion capabilities which would ensure a vigorous add-on marketplace.

OMNI-BOT

Remember the plastic mechanical Armatron™ robot arm? Tomy, the company which originally introduced that toy into this country, has introduced its newest robot toys: Dingbot,™ Ver-bot,™ and Omni-bot.™ The machine which will be most interesting to experimentalists is the Omni-bot.

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Make no mistake, Omni-bot, shown in Photo 2, is definitely a toy. It is designed for children of all ages. The Omni-bot is two feet tall and comes complete with an onboard microcomputer and cassette tape deck, a remote control transmitter, digital alarm clock, built-in microphone, and manual grasping hand. The arms can be moved manually and lock into whatever position you move them.

Omni-bot is programmed through a remote control transmitter. It can be instructed to repeat up to seven different programs at designated times—up to seven days in advance. Program move sequences can be stored on an audio cassette tape and played back to repeat motions. Unfortunately, the Omni-bot has very little, if any, onboard computer memory. Therefore, all program sequences are obeyed sequentially from the audio cassette. Omni-bot has no onboard decision making capabilities or sensors. It is simply an interesting toy. However, my experience with previous Tomy toys indicates that the real fun will start when you take the Omni-bot apart.

Since Omni-bot appears to be screwed together, enterprising experimentalists can disassemble the robot and add their own circuitry. One interesting addition would be substituting programmable memory for the cassette storage. The audio tape must store information which is converted into digital data at some point. It just might be possible to reroute the data to some random access programmable memory instead of the cassette tape. This addition would potentially allow the robot to be programmed with repeat loops and decision branches. Considering the Omni-bot's retail price of $250, this could provide an experimentalist with a rather inexpensive robot device.

I look forward to hearing about various experiments anyone might perform on this robot toy.

RADIO CONTROL

Fidelity Computer Products, Inc. (the people who brought you the Chess Challengers) displayed their new radio

Continued on page 45

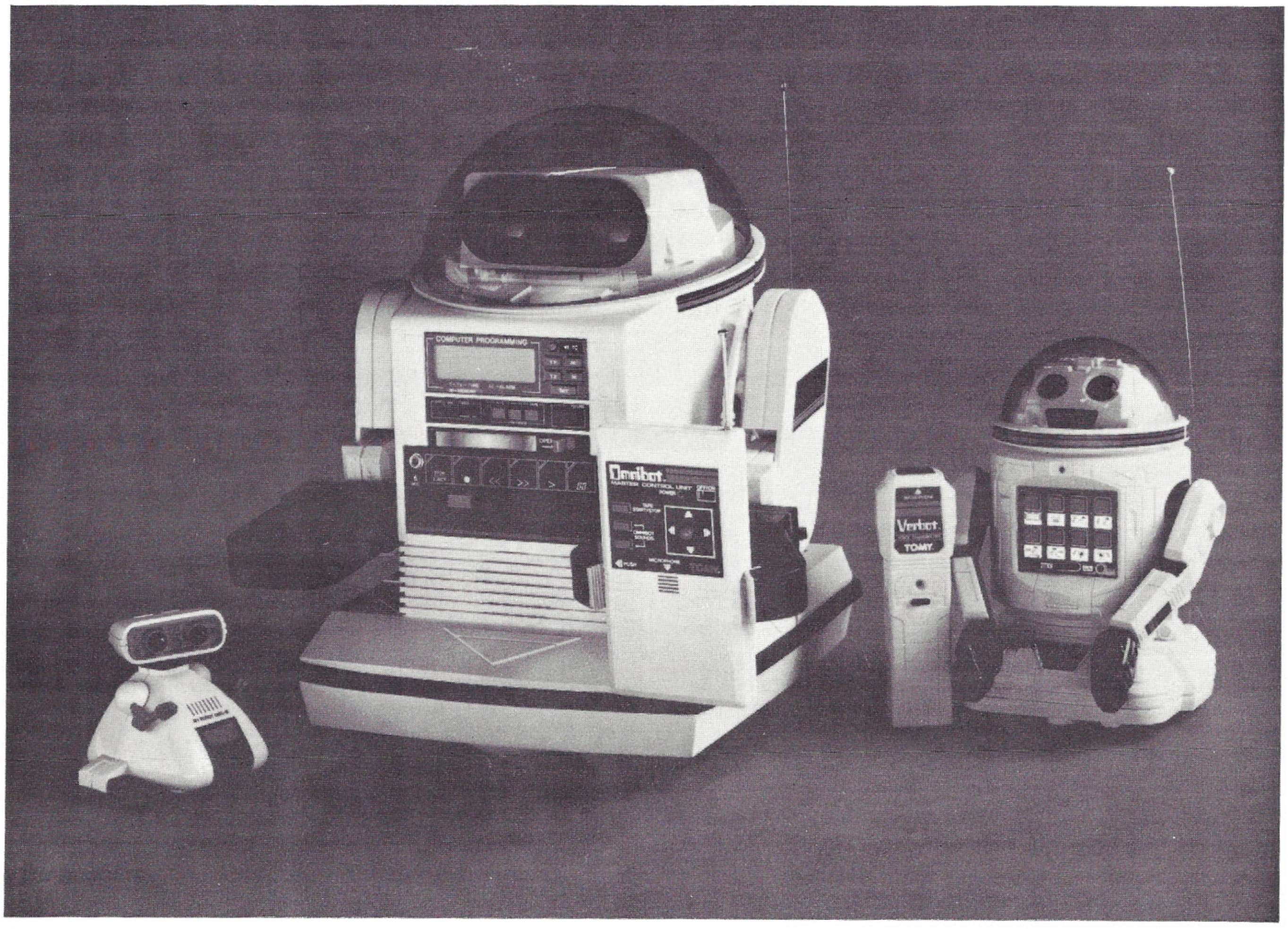

Photo 2. From left to right, the Tomy robots are Ding-bot (a little toy which bounces off walls and runs around the floor), Omni-bot (Tomy's top-of-the-line robot toy with built-in clock and cassette recorder), and Ver-bot (a voice-actuated machine which responds to eight spoken commands).

AUGUST

1–3 August. The Computer: Extension of the Human Mind. Eugene, OR. Contact: Summer Conference Office, College of Education, University of Oregon, Eugene, Oregon 97403.

This conference, the third annual computer and instructional technologies conference to be sponsored by the Center for Advanced Technology in Education, will focus on the needs of the individual who has become responsible for school and district level use of computers and other emerging instructional technologies. Both general and special interest group sessions will be supplemented with an extensive vendor hall and film/video theater related to computer technology in education. Pre- and post-conference workshops will be conducted on the educational uses of computers.

Artificial Intelligence: Are We Being Outsmarted? The Rensselaerville Institute, Rensselaerville, NY. Contact: Mary-Ann Ronconi, Public Programs Coordinator, The Rensselaerville Institute, Rensselaerville, NY 12147.

AI: Are We Being Outsmarted? is a public hearing to discuss the impact and future of artificial intelligence research. Invited speakers include Isaac Asimov, Marvin Minsky, M. Mitchell Waldrop (science journalist), Janet Jeppson (psychiatrist and science fiction writer), Mark Chatrand III (VP of the National Space Institute) and Isidore Adler (NASA consultant and geochemist). The forum will discuss the definition of intelligence, whether intelligence implies meaning, how real is the problem of job displacement, and what is the best scale to use in balancing the positive and adverse affects of AI.

5-8 August. Lisp and Functional Programming. University of Texas at Austin. Contact: Robert S. Boyer, University of Texas at Austin, Institute for Computing Science, 2100 Main Building, Austin, TX 78712, telephone (512) 471-1901.

This is the third in a series of biennial conferences on the Lisp language and issues related to applicative languages. Areas of interest include implementation problems; programming environments; large implementations; support tools; architectures; microcode and hardware implementations; significant language extensions; lazy evaluation; functional programming; logic programming; combinators; FP; APL; Prolog; and other languages.

6–10 August. AAAI-84. University of Texas, Austin, TX. Contact: American Association for Artificial Intelligence, 445 Burgess Drive, Menlo Park, CA 94025, telephone (415) 328-3123.

AAAI-84 is the fourth national conference sponsored by the American Association for Artificial Intelligence and a local university. The purpose of the national conference is to promote scientific research in the field of artificial intelligence by bringing together representatives from government, industry, and academic and research communities. The program is divided into Tutorial, Technical, and R&D programs. This year's conference topics include AI and education, AI architectures and languages, automated reasoning, cognitive modelling, expert systems, learning, knowledge representation, natural language, perception, philosophical and scientific foundations, and robotics.

20–24 August. National Conference and Exhibition on Robotics—1984. Melbourne, Australia. Contact: The Conference Manager, Institution of Engineers-Australia, 11 National Circuit, BARTON, A.C.T. 2600, AUSTRALIA, telephone (062) 73-633.

This conference promises to be the most important Australian robotic event held to date. It will have a strong application and education emphasis. Leading Australian robot users, developers, and researchers will present their experience and views on this important high-technology area.

21–24 August. 1984 International Conference on Parallel Processing. Hilton Shanty Creek Lodge, Bellaire, MI. Contact: Dr. Robert M. Keller, L-306, Computing Research Group, Lawrence Livermore National Lab, PO Box 808, Livermore, CA 94550, telephone (415) 422-0499.

The conference will discuss various aspects of parallel processing algorithms and machinery. Tentative topics include scientific computation, distributed systems, interconnection, artificial intelligence, numeric computation, image processing, applications, queueing analysis, vector machines, scheduling, computer networks, languages, simulation, memory systems, and dataflow models.

27–30 August. Adaptive Control—Design and Applications, Course. University of California, Berkeley, CA. Contact: Continuing Education in Engineering, University of California Extension, 2223 Fulton St., Berkeley, CA 94720, telephone (415) 642-4151.

Intensive four-day course intended for professionals engaged in the design and implementation of modern control systems, such as engineers and computer-applications specialists involved in designing real-time monitoring and control systems or in developing control software. Emphasis will be on providing a clear understanding of various adaptive control techniques, including on-line identification schemes, as well as on future trends in system design. Case studies and computer laboratory sessions will supplement course lectures.

29–30 August. An Applications-Oriented Approach to Artificial Intelligence (Course 994DC). George Washington University, Washington, DC. Contact: George Harrison, George Washington University, Continuing Engineering Education, Washington, DC 20052, telephone (202) 676-6106.

The purpose of this course is to provide an understanding of the design, application, and implementation of an *intelligent* system based on artificial intelligence processing techniques that are directly applicable to the solution of practical problems. The course also discusses how to choose from among the many available options in selecting or designing intelligent systems based on artificial intelligence processing techniques. The program is intended for project and design engineers, scientists, systems analysts, and technical managers who have responsibilities for specifying, designing, and implementing artificial intelligence–based systems.

SEPTEMBER

10–13 September. 10th Annual Advanced Control Conference. Fowler Hall, Stewart Center, Purdue University, West Lafayette, IN. Contact: Edward J. Kompass, Control Engineering Magazine, 1301 South Grove Ave., PO Box 1030, Barrington, IL 60010, telephone (312) 381-1840.

This year's conference celebrates the 25th anniversary of the application of digital computers to industrial control. Twenty-two applications papers will support the four specially-commissioned, two-hour tutorials. Topics include: a view of the beginnings and development of computer-based industrial control, the merging of discrete and continuous process control, the beginning of computer-based digital control systems, and a future scenario for computer-based digital control systems. Applications papers cover: array processors, fiber optic data buses, micro and personal computer packaging for industrial applications, personal computer software packages for industrial control, industrial I/O for personal computers and the role of humans in fully computerized industrial plants.

14–16 September. Heart of Texas Computer Show. Bayfront Plaza, Corpus Christi, TX. Con-

tact: Heart of Texas Computer Show, PO Box 12094, San Antonio, TX 78212, telephone (512) 681-2248.

The show features vendors displaying the latest in small business and personal computer systems, with robots, games, and other high-tech products. Educational seminars are also planned.

24–26 September. Robotics Seminar. IEE Education Center, Technology Park/Atlanta, Norcross, GA. Contact: Institute of Industrial Engineers, Conference Department, 25 Technology Park/Atlanta, Norcross, GA 30092, telephone (404) 449-0460.

The Robotics Seminar is designed to acquaint participants with the variety of equipment available and how and where robots might be used effectively. Special seminar features include a full-day laboratory experience where participants can see robots in action and a workshop session for discussing and analyzing potential robot applications.

25–26 September. NASA Symposium on Productivity and Quality: Strategies for Improving Operations in Government and Industry. Capital Hilton Hotel, Washington, DC. Contact: Pamela Edwards, AIAA, telephone (212) 581-4300.

The symposium is sponsored by NASA and organized and operated by AIAA.

25–27 September. International Industrial Controls Conference and Exposition (IIC '84). Philadelphia Civic Center, Philadelphia, PA. Contact: Tower Conference Management Co., 331 W. Wesley St., Wheaton, IL 60187, telephone (312) 668-8100.

Preliminary session titles include: *Advances in Information Flow Networks; Highways for Factory Automation; Vision; User-friendly Software for Programmable Controllers; Fiber Optics;* and *Robotics*.

OCTOBER

2–4 October. 14th International Symposium on Industrial Robots. Gothenburg, Sweden. Contact: Swedish Trade Office, 4000 Town Center, Suite 202, Southfield, MI 48075, telephone (313) 352-6990.

Nearly 1,000 delegates are expected to participate in this year's symposium. In connection with the symposium, there will also be an extensive international exhibition showing the latest developments and achievements in the field of industrial robots.

2–4 October. AUTOFACT 6. Anaheim Convention Center, Anaheim, CA. Contact: Gregg Balko, Computer and Automated Systems Association of SME, One SME Drive, PO Box 930, Dearborn, MI 48121, telephone (313) 271-1500.

AUTOFACT 6 will feature a comprehensive program of tutorials and conference sessions covering the entire spectrum of computer-integrated manufacturing—from design and engineering, through fabrication, assembly, inspection and testing, to shipping.

2–5 October. Robot 84, Scanautomatic 84, and The 14th International Symposium on Industrial Robots. Gothenburg, Sweden. Contact: Swedish Trade Fairs Foundation, Box 5222, S-402 24 Goteborg, SWEDEN, telephone 46 31 20 00 00.

Three major international events devoted to the design, production, and uses of industrial

robots will take place in the Swedish Trade Fair halls simultaneously in October. Robot 84 is an international exhibition of industrial robots and control systems for materials handling, assembly, and complex production tasks. Scanautomatic 84 covers industrial computers and the pneumatic, hydraulic, and electronic components which provide the backup technology for industrial automation. The Symposium on Industrial Robots is organized jointly by the Swedish Trade Council, the Swedish Trade Fairs Foundation, and MEKAN, Sweden's largest industrial association.

ACM-84, The Fifth Generation Challenge. San Francisco Hilton, San Francisco, CA. Contact: ACM-84, PO Box 32575, San Jose, CA 95152, telephone (415) 948-6306.

The Japanese Fifth Generation supercomputers pose a challenge to American computer manufacturers. The ACM-84 Conference topic areas attest to the concern about the Japanese challenge: supercomputers; developments in artificial intelligence; robotics and sensing; the impact of the fifth generation; limits on technology transfer; applications for the 1990s in business, education, manufacturing, research, and the professions; and anticipated changes in society.

10–12 October. InteRobot-West '84. Long Beach Convention Center, Long Beach, CA. Contact: Tower Conference Management Co., 331 W. Wesley St., Wheaton, IL 60187, telephone (312) 668-8100.

InteRobot-West '84 offers 20 technical conference sessions, three special-interest tutorials, and 80 internationally recognized speakers and session chairmen. Session titles include: *Industry Overview; Tooling Design; Machine Languages; Machine Vision; Machine Sensors; Robots in the Foundry; Personal and Educational Robots; Education in Robotics;* and *Emerging Robot Applications.*

25–27 October. Robotics Seminar. IIE Education Center, Technology Park/Atlanta, Norcross, GA. Contact: Institute of Industrial Engineers, Conference Department, 25 Technology Park/Atlanta, Norcross, GA 30092, telephone (404) 449-0460.

The Robotics Seminar is designed to acquaint participants with the variety of equip ment available and how and where robots might be used effectively. Special seminar features include a full-day laboratory experience where participants can see robots in action and a workshop session for discussing and analyzing potential robot applications.

NOVEMBER

4–9 November. Intelligent Robots and Computer Vision. Hyatt Regency, Cambridge, MA. Contact: SPIE—The International Society for Optical Engineering, Bellingham, WA 98227-0010, telephone (206) 676-3290.

The emphasis for the 1984 conference is on intelligent robots, vision, and sensor systems. The intent of the sessions is to address and interchange ideas on a wide range of applications, issues, and techniques for these advanced intelligent systems. State-of-the-art technical design and modern equipment concepts will be presented. Topics to be addressed and for which contributed papers are requested include: government and industrial programs in intelligent sensors and robotics; applications of intelligent sensor systems; statics, kinematics, dynamics, and control of robot systems; standards for sensors and robots; image processing; feature extraction; three-dimensional object representation; use and application of artificial intelligence; and image understanding in intelligent robotics and computer vision.

16–17 November. 6th Annual Forth Convention. Hyatt Palo Alto, Palo Alto, CA. Contact: Forth Interest Group, PO Box 1105, San Carlos, CA 94070, telephone (415) 962-8653.

The Forth Interest Group is a worldwide nonprofit organization of over 4700 members and 53 chapters devoted to the Forth computer language. The convention is prepared to meet the needs of every Forth enthusiast—beginner to professional—with two days of hands-on tutorials, exhibits/vendor booths, lectures, and discussions.

27–29 November. Robots-West. Anaheim Convention Center, Anaheim, CA. Contact: Jeff Burnstein, Robot Institute of America, PO Box 1366, Dearborn, MI 48121, telephone (313) 271-0778.

Robots-West is RIA's first regional show. It will feature exhibits by leading robot manufacturers and component suppliers. Approximately 6,000 visitors are expected to attend the three-day exposition and conference.

ROBOTICS AGE BACK ISSUES

SUMMER 1979: Digital Speed Control of DC Motors; Industrial Robots '79; Introduction to Robot Vision; The Grivet Chess-Playing Arm. **(photocopy)**

WINTER 1979: Advances in Switched-Mode Power Conversion, Part 1; Prospects for Robots in Space; Robotics Research in Japan, Report from IJCA16.

SPRING 1980: Microcomputer Based Path Control; Robotics Research in France; Multiple Sensors for a Low-Cost Robot; the Robots of Autofact II; Inside Big Trak.

SUMMER 1980: Industrial Robots; Today and Tomorrow; Introducing the Minimover 5; Advances in Switched Mode Power, Part II.

FALL 1980: Using Optical Shaft Encoders; Interview with Victor Scheinman; Robot Vision for Industry; The Autovision System; Industrial Robotics '80; Robots on Your Own Time; Superkim Meets ET-2.

JAN/FEB 1981: A Robot Arm Without a Budget; An Interview with Joseph Engelberger; Robots V—Dearborn 1980; Robots on Your Own Time; Opto "Whiskers," Robot Toy Designs.

MAR/APR 1981: Video Signal Input; Chain-Code; Camera Geometry for Robot Vision; TIG Welding with Robots; Robot Digestive Track—Robots on Your Own Time.

MAY/JUNE 1981: Rehabilitative Robots; A Homebuilt Computer Controlled Lathe; An Interview with Charlie Rosen; Superkim Meets ET-2, Part II.

JULY/AUG 1981: Segmenting Binary Images; The Robot as Transfer Device; Continuous Path Control of Stepper Motors; TIMEL: A Homebuilt Robot.

SEP/OCT 1981: Bullish Days in the Robot Business: Edge Detection in Man & Machine; Continuous Path Control with Stepping Motors; Build a Low-Cost Image Digitizer, Report from JACC-81; The Robot Builder's Bookshelf.

NOV/DEC 1981: Teach Your Robot to Speak; Fast Trig Functions for Robot Control; An Interview with George Devol; The Great Japanese Robot Show; TIMEL: A Homebuilt Robot, Part II.

JAN/FEB 1982: Avatar: A Homebuilt Robot; A Look at SS-50 Computer Boards; Working Within Limits; Ambulatron: Another Contest Winner; Quester.

MAR/APR 1982: The Rhino XR-1: A Hands-On Introduction to Robotics; Power for Robots; A Computer Controlled Sentry Robot: A Homebuilt Project Report; Natural Language Understanding: A First Look; RT-13 Video/Sound Recognition System; An Inexpensive Hand; Type 'N Talk.

MAY/JUNE 1982: Part Sources for Robots; An Inexpensive Arm-Hand System; The Polaroid P100 Polapulse Battery: Solution Waiting for a Problem; New Robot Books for the Bookcase: Applying Robot Vision to the Real World; Robots VI: A Landmark in an Exciting Era; Photo Essay and Notes from Robot VI.

JULY/AUG 1982: The Microbot Teach-mover; Some Notes On the Rhino XR-1 and Minimover 5; Patent Probe; Use Your Apple As a Robotics Development System; IBM Robots; Adapting a Speech Synthesizer; Constructing an Intelligent Mobile Platform, Part I.

SEPT/OCT 1982: Roving Robots; Report on SIGGRAPH '82; Patent Probe No. 4,221,997; Constructing an Intelligent Mobile Platform, Part II; The Physics of One-Legged Mobile Robots.

NOV/DEC 1982: Robot Wrist Actuators; Patent Probe; A Microcomputer Based, Real-Time Robot System; The Physics of One-Legged Mobile Robots; Part II; 1982 AAAI Conference; Armatron: A Study in Arm Engineering; Invention Documentation: A Primer.

JAN/FEB 1983: The Move-Master RM-101; Mailmobiles in the Office; Teaching the Rhino XR-1 to Write; The Philosophy and Birth of Computer Science; The 2-Roll Gripper.

MAR/APR 1983: Nuclear Power Plant Emergency Damage Control Robot; Artificial Intelligence and the Nature of Robotics; Patent Probe: Driverless Vehicle Autoguide; Lamberton Robots.

MAY/JUNE 1983: Patent Probe: Multi-Purpose Mechanical Hand; XY Interpolation Algorithms; Designing With Optical Shaft Encoders; A Table of Contemporary Manipulator Devices; An Algorithmic Approach to Intelligent Robot Mobility.

JULY/AUG 1983: The Get Away Special, Part I; A Nose for the Heath Hero-1; Patent Probe: Ambulatory Platform; Robotics and the Law: Organizing the Venture; A Table of Contemporary Manipulator Devices.

SEPT/OCT 1983: ODEX 1: The First Functionoid; A Cog-Wheel Driven Robot Cart; A Table of Contemporary Manipulator Devices; Patent Probe: A Portable Robot Task Analyzer; The Penpad: Handwritten Input for Computers; The Get Away Special, Part II: Flight Preparations.

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JANUARY 1984: Robots in Batch Manufacturing; Super Armatron; Directory of Robotics Education and Training Institutions; A Table of Contemporary Manipulator Devices; Patent Probe: A New Robot Patent Category; Operator Roles in Robotics; The Scorpion: Software Overview.

FEBRUARY 1984: GRASP: From Computer Aided Robot Design to Off-Line Programming; Design and Construction of a Five-Fingered Robotic Hand; Patent Probe: Omnidirectional Vehicle; Using Microprocessors with Radio-Control Servos; Designing a Reliable Voice-Input Robot Control Language; Part II, The Scorpion: Motor Control Instructions.

MARCH 1984: Part I, Armega 33: Mechanical Design; Patent Probe: Robot Computer Chess; Part III, The Scorpion: Commands with Responses; A Simple Computer Interface.

APRIL 1984: Closing the Sensor-Computer-Control Loop; Bipedal Balance; Patent Probe: Robot Warehouse; Part II, Armega 33: The Electrical Components.

MAY 1984: Backyard Foundry for Sand Casting; Androtext, A High-Level Language for Personal Robots; Part III; Armega 33: Computer Control; Computers in the Real World.

JUNE 1984: Introduction to Numerical Control Programming; Glossary of CNC and Machine Tool Technology; A Glance at Some Microprocessor-Controlled CNC Tools; Intel's Bitbus Microcontroller Interconnect.

JULY 1984: Shape Memory Effect Alloys for Robotic Devices; Hitachi's Robot Hand; Part II, Backyard Foundry for Sand Casting: Making the Molds; Fantasy Meets Reality at New York Robot Exhibit; Meccano and the Home-Built Robot; The Role of Robots in Flexible Manufacturing Systems; A Review of the Colne Armdroid I.

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STACK-ORIENTED COMPONENTS. National Semiconductor has introduced the M2000 Macrocomponent™ family. The family consists of a set of little black boxes, approximately 2 in. wide by 4 in. long by 1 in. high. Each one of the little black boxes performs a specific function. National Semiconductor has already announced a 16 Kbyte CMOS static programmable memory, a CMOS Z80 processor system, an RS-232 serial interface, a memory storage module, a Forth language interpreter, 16 Kbyte programmable memory with battery backup, and a base plane with power supply. Future products include CMOS data acquisition, floppy disk controller, 300 bps modem, EEPROM module, and digital I/O.

The most intriguing thing about these products is how they are assembled. Each module consists of a printed circuit board with surface mounted components. Some of the modules have more than one board and more than one side of the board populated. A series of pins on the bottom matches the socket on top of each module. To add a new module to an already existing system, simply place the component on top of the stack. Each module contains its own address decoding so the order in which the system is assembled does not affect the overall function. National Semiconductor reports that at least 20 modules have been stacked without any difficulties.

Although firm prices have yet to be set, the modules should each be priced around $100. Assuming this holds for every module, you could build a computer system consisting of a base plane, processor module, two RS-232 ports, Forth interpreter, 16 Kbytes of programmable memory, and a floppy disk controller for approximately $600.

National Semiconductor can be reached at 2900 Semiconductor Drive, Santa Clara, CA 95051, telephone (408) 721-5000.

LANGUAGES, OLD. Back in my college days, I discovered a language manual sitting in the corner of the university programming center describing a then little-used language called SNOBOL4. SNOBOL (which stretches an acronym for StriNg Oriented SymBOlic Language) was an incredibly large, time-chewing, memory-munching language used for manipulating text. Its uses ranged from writing powerful text editors to developing some of the earliest natural-language parsing algorithms. SNOBOL's forte was pattern matching, the ability to find complex textual patterns imbedded in strings. Perhaps one of the best known examples is the Eliza program which parses phrases entered by a user and attempts to generate a comment based on what has been entered.

Until now, SNOBOL required a mainframe computer and lots of processor time. Berstis International is marketing the Minnesota implementation of SNOBOL4 on the IBM PC. According to the manual, this is a full implementation of SNOBOL4 although some of the system-dependent instructions return nulls. Although it will run on a 128 Kbyte system, the manual suggests you load up as much memory as you can afford. I'm amazed they managed to get it running at all in 128 Kbytes. Perhaps the most amazing part about the product is the price, $39.95. However, don't expect a lot of support. This is user-supported software which

means, aside from an occasional newsletter, you are on your own. However, the documentation allowed me to get the software up and running the demo programs within five minutes.

For people interested in SNOBOL4 but unfamiliar with the language, Berstis International sells several of the best-known books on the language. This software package looks like a real buy for anyone interested in unusual programming languages or looking for powerful pattern matchers to write natural language parsing routines. Berstis International can be reached at PO Box 441, Millwood, NY 10546.

LANGUAGES, NEW. Q'Nial™ (Queen's University Nested Interactive Array Language) is an interactive programming language said to combine the best abilities of Lisp and APL. Q'Nial can operate on arrays and lists of data as easily as it does on single data values. All data is stored in structures called arrays. A single, indivisible entry, such as a number, is called an atomic array. The term *nested* indicates that arrays can contain arrays that contain arrays, etc. Powerful built-in commands can be used to manipulate the arrays, compare them, and map them onto each other. This mapping function is very useful in both vision and AI projects.

For more information about Q'Nial, contact: Nial Systems, Ltd., PO Box 2128, Kingston, Ontario K7L 5J8, CANADA, telephone (613) 549-1432.

RIA GROWTH. Membership in the Robotic Industries Association (RIA) has reached an all-time high of 295. According to Donald A. Vincent, RIA Executive Vice President, "The addition of personal robot manufacturers and developers plus the creation of the new RIA Vision Group are major reasons for the strong surge in membership."

The 15 personal robot manufacturers who have joined RIA since January 1 are Androbot, Inc.; Cal-Robot; Colne Robotics, Inc.; Digi-Tech, Inc; Heath Company; Harmonic Drive; RB Robot Corp.; Rhino Robots, Inc.; The Robot Factory; The Robotics Center; Robot Shop; Show America, Inc.; Technical Micro Systems, Inc.; Terrapin, Inc.; and Industrial Robotics, Inc.

RIA can be reached at PO Box 1366, Dearborn, MI 48121, telephone (313) 271-0778.

SIGHT ON TOMORROW. The Westinghouse Electric Corp has presented Carnegie-Mellon University with a $1 million grant of funds and equipment over a three-year period to establish an Optical Data Processing Center. According to Dr. John Hulm, acting general manager of the Westinghouse Research and Development Center in Churchill, "Optical technology is a major technology wave of the future." Westinghouse expects that CMU's expertise in basic research in the field of optical data processing will "not only advance the state of the art, but will also result in a prolific output of graduate students with expertise in the technology." The Optical Data Processing Center will be headed by Dr. David Casasent, George Westinghouse Professor of Electrical and Computer Engineering at CMU.

Animate vs. Inanimate

Carl Quick
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Orlando, FL 32821

If you have a laboratory in which to do all of your robot development work, consider yourself very fortunate. However, if you are like me and constrained to using your house as a laboratory, you have probably already encountered the problem of running into warm bodies, be they dogs, cats, or people. Of course, the last thing you want is a robot that runs over the spouse or household pet. The robot needs a sensor to distinguish between animate and inanimate objects.

Other than using some sort of camera system and very elaborate image processing algorithms, the easiest alternative is to use a sensor that measures the temperature or black body radiation of the encountered object.

The peak emission from a human being, resulting from the natural body temperature, occurs at 10 μm. This is in the infrared range. You can also assume that a healthy human being emits approximately 100 W of detectable radiation. With suitable optics, it is therefore possible to detect an infrared signal from a warm body at well over 100 meters.

Various passive infrared (IR) detectors are available for use with burglar alarm systems or for opening and closing doors. These detectors, however, have one drawback for a robot application: the person must be moving in order to be detected. The movement causes an AC signal to be generated in the sensor. This signal is what indicates the presence of a warm body. In this application, the robot is required to approach an object and determine if it is animate or inanimate, regardless of whether the object is moving or stationary.

My quest for this type of sensor finally ended with a company called Eltec Instruments, Inc. The sensor and electronics board are shown in Photo 3. The sensor head, which contains an Eltec 4192 detector, comes preassembled in a special holder with a Fresnel lens. The Fresnel lens, a key part in the system, gathers infrared energy and focuses it on the detector element. The sensor head is connected to the electronics board with three wires. The sensor and electronics require +12V at 55 mA, making it ideal for use in robotics work.

I fabricated an aluminum piece to hold the sensor head assembly and mounted it and the electronics board beneath the built-in sonar ranger. This allows the sonar and infrared detector units to look at the same object. The sonar ranger has an approximate range of eight feet, so the characteristics of the Fresnel lens used in the sensor head were matched as closely as possible to this. I obtained test results by measuring the range distance from the center of the robot and then measuring how far away from the center line the

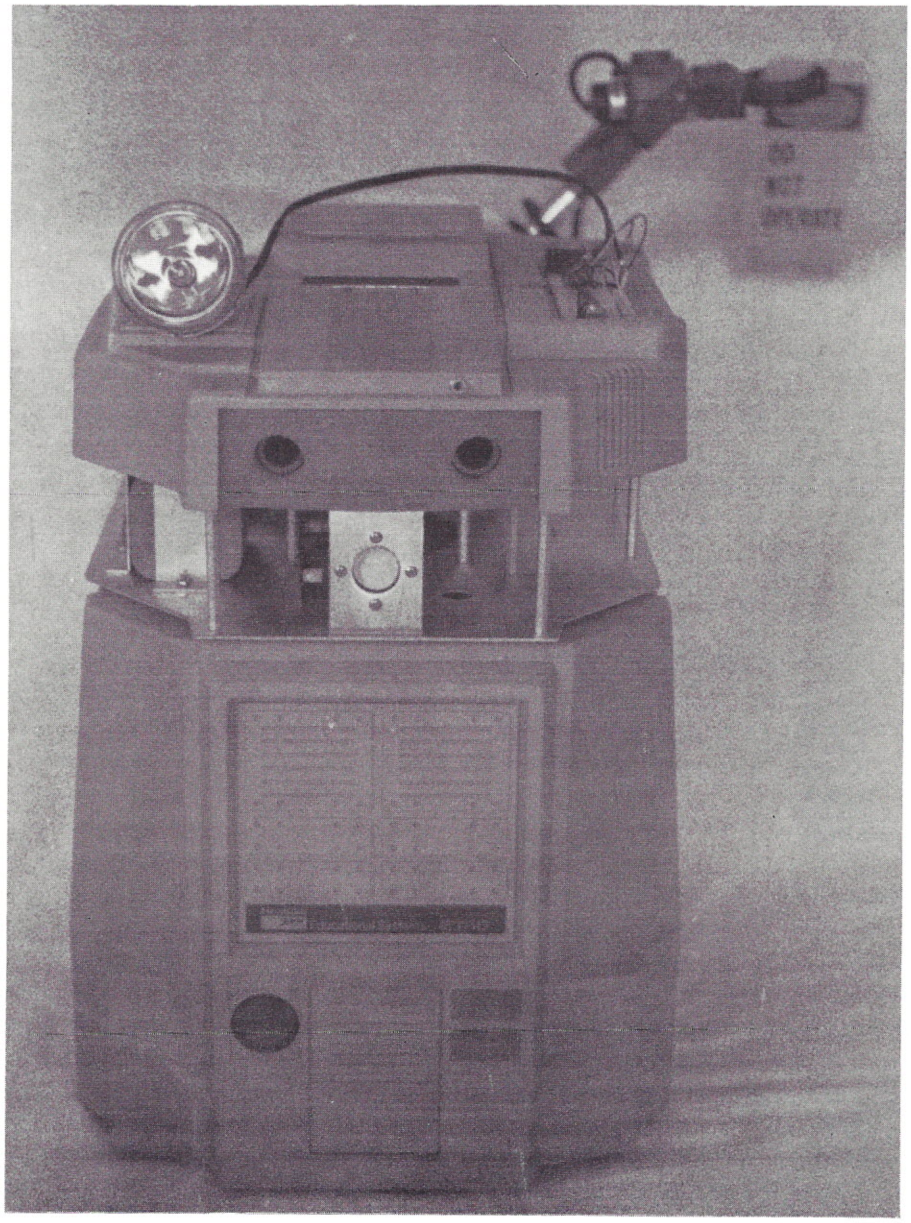


Photo 1. The modified HERO 1 has a Polaroid ultrasonic scanner mounted in the front panel and a miner's headlamp on the head. The infrared scanner is mounted beneath the original HERO 1 ultrasonic ranging system.

detector could sense a warm object. The sensor actually has a much greater range than that of the built-in sonar ranger and comes very close to that of the Polaroid range finder (approximately 35 ft.), but for now, I am only concerned with objects within eight feet.

Figure 1 shows the test setup and results. The electronics board has two adjustments labeled *gain* and *hold*. Gain adjusts the detector receiver gain and was adjusted very slightly to optimize it for the desired range. Hold varies the length of time a detection is held.

INTERFACING

The electronics board provides two types of output when a detection is made. The first output is a visual indication via an LED. The second is a relay with three contacts—a common, a normally closed, and a normally open. The relay outputs could be used, but I chose to remove them. This reduced the current consumption to

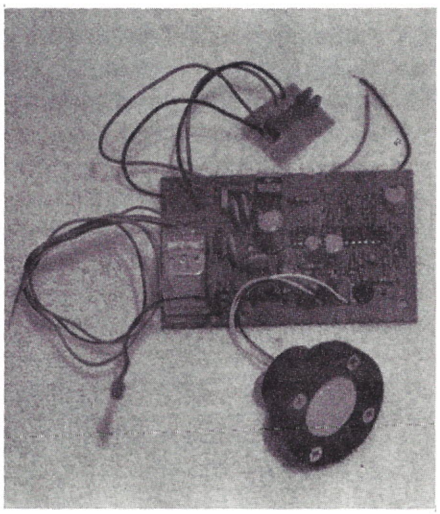
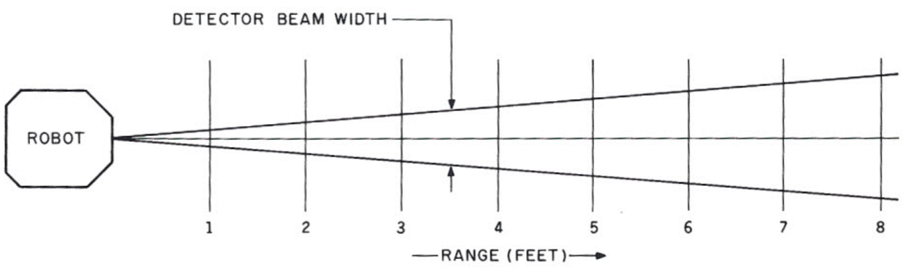


Photo 3. The infrared detector, installed in an optical base, and the associated control electronics. The entire assembly is available from Eltec Instruments.

13 mA and reduced the weight by 1 oz. These reductions may seem insignificant, but when dealing with robots, you must consider them mobile platforms with limited weight and power capabilities.



RANGE	DETECTOR BEAM WIDTH
1 FOOT	4 INCHES
2 FOOT	5 INCHES
3 FOOT	6 INCHES
4 FOOT	7 INCHES
5 FOOT	10 INCHES
6 FOOT	12 INCHES
7 FOOT	13 INCHES
8 FOOT	14 INCHES

Figure 1. Robot test ranging setup and results.

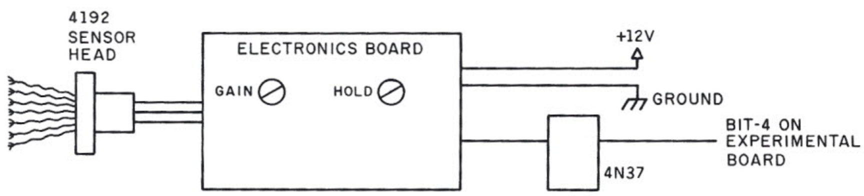


Figure 2. The sensor head is connected to the Eltec electronics board. The board output is connected to bit 4 of the HERO 1 experimental board through a 4N37 opto-isolator.

I used the experimental board on the Heath HERO 1's head as the interface to the sensor electronic board. I used a GE opto-isolator (4N37) to connect the Eltec sensor to the Heath interface board. The input to the opto-isolator is connected to the output on the sensor electronic board which turned on the relay. The output from the opto-isolator is connected to Bit-4 on the experimental board input port (address hexadecimal C2A0). Figure 2 shows how the sensor is connected.

This type of passive infrared sensor needs to be turned on for several seconds before being used. This allows the sensor to stabilize. I always keep the sensor turned on whenever the Hero 1 is activated.

SOFTWARE

The task of reading the sensor is performed by the following simple code:

```
LDAA EXPBD ;get data from ex-
            perimental board
ANDA MASK4 ;mask off unwanted
            bits
BEQ NXTSK  ;if zero then no detec-
            tion
??? ?????  ;else take appropriate
            action
```

However, incorporating the new sensor data into an existing program or building a program around the new sensor data is where the challenge lies. I had previously written a program called Roam for the HERO 1 which allows it to explore areas without colliding into objects. This program is based on the Spur algorithm described in the May/June 1983 issue of *Robotics Age*, ("An Algorithmic Approach to Intelligent Robot Mobility," Scott Kauffman, pp. 38-47).

The program worked well, but the robot became confused if it approached an object, computed its coordinates, stored the coordinates in the memory map, recomputed its direction, and then found another object had suddenly appeared in what used to be a clear path. As it turned out, these suddenly-appearing objects were animate. With the new sensor data available, this problem no longer occurs. Any encountered object that is found to be animate is not stored in the map. The robot also speaks the following message when an animate object appears: "Would you please

NOTES ABOUT TUBBY

As you will notice from Photo 1, my robot Tubby (a Heathkit ET-18, HERO 1) has undergone some extensive modifications. A miner's headlamp is mounted on the head next to the area where the keyboard was located. This light is controlled by the computer through an SN75452N lamp driver mounted on the experimental board. An idea for future implementation is to enable the robot to remove this light with his gripper and illuminate a particular area.

The original keyboard and display have been removed to make space for my own design CCD camera. All data entry and control now comes from the remote keyboard/display or from any personal computer with an RS232 serial interface. The serial interface is controlled by a simple command monitor which I stored in an EPROM and placed in the expansion ROM socket on the processor card. The monitor program interfaces directly with the existing robot operating system and allows me to use any of the previously defined commands plus some new ones which allow me to send or receive data from the robot. I also added a switch to the head which allows me to disable the voice when it gets tiring.

Mounted on the front body panel is one of Polaroid's ultrasonic ranging systems. My ranging system is from one of Polaroid's early experimenter's kits and has seen active duty in several projects. The ranger is connected to a parallel port on Micromation's MEMCOM board. The MEMCOM board is one of the best expansion boards available. It not only gives you an extra 30 Kbytes of programmable memory and an RS232 serial port, but there is also a dual parallel port implemented with the 6522 VIA (Versatile Interface Adapter) and a wire-wrap area for prototyping with all 6808 processor signals available.

I purchased a few 3 in. aluminum spacers and raised the existing hardware on Tubby's head to allow room for expansion. I am currently fabricating some panels to match the existing bodywork. In this newly-available area, below the built-in ranger, I mounted the sensor for distinguishing between animate and inanimate objects.

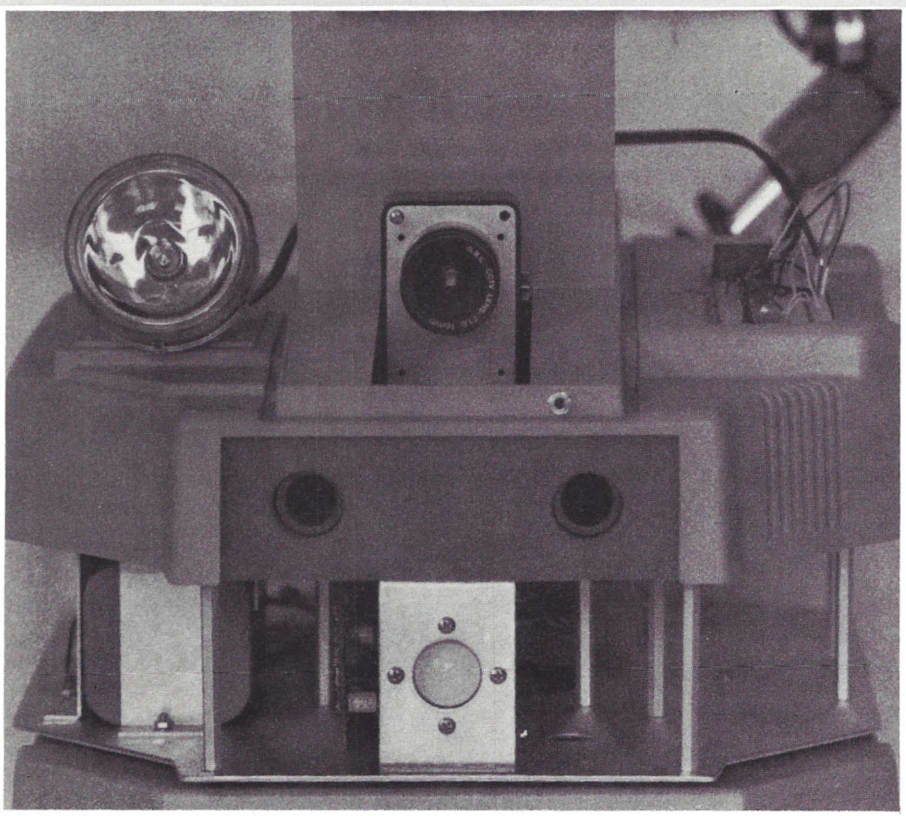


Photo 2. A closeup of the HERO 1's expanded head module with a miner's lamp, a custom-designed CCD camera, and the infrared animate vs. inanimate sensor installed under the ultrasonic ranging system.

ADDRESSES

Eltec Instruments, Inc.
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(904) 253-5328

Heath Educational Systems
Benton Harbor, MI 49022
(616) 982-3200

Micromation, Inc.
9104 Red Branch Rd.
Columbia, MD 21045
(301) 730-1237

move because it is easier for you to go around me than for me to go around you."

A program currently under development uses the new sensor for its primary data input. This program, called Follow the Leader, allows the HERO 1 to follow an animate object at a certain distance. The only problem is I may have to add a second passive infrared sensor to help track animate objects when they move across the field of vision. One other possibility is to use my soon-to-be-completed onboard camera.

CONCLUSION

My solution for differentiating animate versus inanimate objects is in no way complete nor is it the only one. I hope that it has enlightened you and perhaps inspired you to think of other alternatives.

Personal robotics is a relatively new field. It involves all the sciences. It is the culmination of mechanical engineering, hardware engineering, and software engineering.

Carl Quick is a Staff Engineer in the software department of Martin Marietta Aerospace. He has been interested in robots for about ten years and has built various types of mobile platforms and an eight-axis arm. Although he is unsure exactly where personal robotics is going, he hopes to contribute to its progress.

Carl wishes to thank Mr. David M. Cima, Director of Marketing at Eltec, for the data sheets and application notes on their sensors and the technical expertise in the unfamiliar field of passive infrared detection.

Reader Feedback

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70	80	90
Excellent	Good	Fair

The Echo II Speech Synthesizer

Michael P. Cote
5 Third Avenue
East Islip, NY 11730

The Echo II Speech Synthesizer is one of the most versatile speech synthesizers on the market today. Although the Echo II board can be used with a minimum Apple II™ system, the accompanying software requires at least 48 Kbytes of programmable memory and one disk drive. If a 16 Kbyte (or larger) memory card is installed in slot zero, you can place the Echo II programs there. Otherwise, the programs reside just below DOS.

The Echo II uses a Texas Instruments' 5220 speech synthesizer chip and can be used in several modes, each offering a different level of control over the particular sounds being heard. The TI 5220 chip uses LPC (Linear Predictive Coding) methods to reproduce speech. The LPC data is stored in memory so that innovative programmers can either change the speech parameters or generate their own words.

INSTALLATION

The Echo II board may be installed in any Apple II expansion slot except slot zero. It comes with its own speaker which can be placed inside the computer at the side of the motherboard. The onboard audio jack is standard, so you can easily connect the synthesizer to other speakers.

The software supplied with the synthesizer automatically searches for the interface board. It is not necessary to specify any particular slot.

THE SOFTWARE

Echo II comes with a set of short demo programs, a text-to-speech translation program, and the Speakeasy program for generating speech at the phoneme level. (Phonemes are the smallest unit of speech, from which all other words are created.) The Speakeasy program takes phonemes and translates them into the LPC data needed by the TI 5220.

The Textalker program demonstrates the Echo II word-to-speech generation mode. This program speaks any text that is written to the Apple II screen. The text is converted to phonemes and the phonemes are passed to the Speakeasy program.

The text-to-speech converter is also available in a separate program. The pro-

```
  5 HIMEM: 32768                              : SET TOP OF VARIABLE MEMORY
 10 D$=CHR$(4):V$=CHR$(22)                    : CHR$(22) PRECEDES WORD
 20 PRINT D$;"BRUN SPEAKEASY"                 : LOAD SPEAKEASY PROGRAM
 30 PRINT V$;"7M!3,"                          : 'MY'
 40 PRINT V$;"7K;2MP%2T'R2,"                  : 'COMPUTER'
 50 PRINT V$;"7KA2N,"                         : 'CAN'
 60 PRINT V$;"7SP&2K,"                        : 'SPEAK'
 70 PRINT V$;"7WI2),"                         : 'WITH'
 80 PRINT V$;"7(UI,"                          : 'THE'
 90 PRINT V$;"+++7E2KO2,"                     : 'ECHO', VOLUME UP
100 PRINT V$;"7T:2---,"                       : 'TWO', VOLUME DOWN
110 PRINT V$;"7SP&3C,"                        : 'SPEECH'
120 PRINT V$;"7SI2N)E2ZS!2ZS!2ZS'R2ZS"        : 'SYNTHESIZERS'
130 END
```

Listing 1. Generating speech using the Speakeasy speech functions.

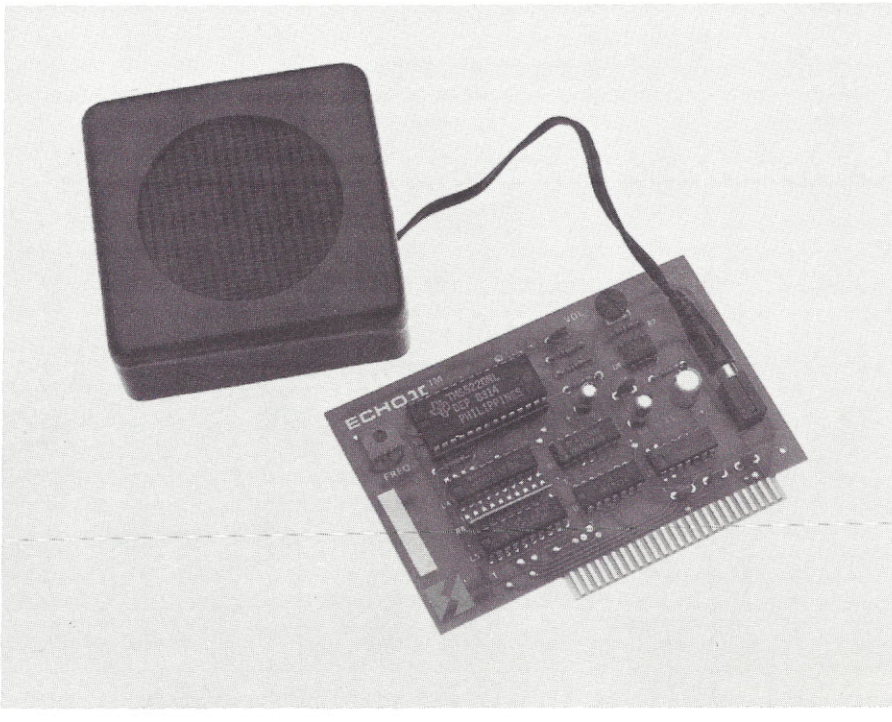

Photo 1. The Echo II Speech Synthesizer for the Apple II computer.

gram converts a line of text into the appropriate phonemes and displays the phonemes on the screen. The program also has a phoneme editor, allowing you to type in a string of phonemes and have the program pass them to Speakeasy so you can hear how they sound.

The Textalker program comes in three versions. One version can be loaded into a 16 Kbyte expansion memory card and contains features to aid blind users. Another version is loaded just below DOS and contains the same features as the expansion memory card version. The smaller third version also loads just below DOS but does not contain the additional features for blind users. All three versions modify the Apple II output vector so that any characters printed on the screen are first diverted to the Textalker program.

The features for blind or visually impaired users are available in the line review mode. The line review mode is entered by pressing control-L. The Echo II verifies the change by saying "review." You can then select the line to review by pressing a key from *A* to *X* corresponding to line *1* through *24* with *1* being the top line. Pressing the RETURN key causes the Echo II to speak the selected line. You can use the left and right arrow keys to make the Echo II speak the next word on the left or the right of the *audio cursor*. Typing a semicolon moves the audio cursor up one line, typing a slash moves the cursor down one line. The review mode can also be instructed to speak a range of lines starting at the current line. Once positioned on the first line to be spoken, typing a comma causes the Echo II to say "to." You can then enter the letter corresponding to the last line to be spoken. To exit the line review mode simply press the ESCAPE key and the ECHO II will respond with the word "exit."

```
10 D$=CHR$(4)                          : CTRL-D FOR DOS COMMANDS
20 PRINT D$;"BRUN TEXTALKER"           : GET TEXTALKER INTO MEMORY
30 PRINT "MY COMPUTER CAN ";           : ALL TEXT PRINTED TO SCREEN IS SPOKEN
40 PRINT "SPEAK WITH THE ";
50 PRINT CHR$(5);"15V";                : SET VOLUME TO 15
60 PRINT "ECHO 2 ";
70 PRINT CHR$(5);"12V";                : SET VOLUME BACK TO 12
80 PRINT "SPEECH SYNTHESIGHZERS"       : MISSPELL SYNTHESIZER TO MAKE IT
                                       :   SOUND CORRECT
90 END
```

Listing 2. Generating speech using the Textalker speech functions to convert words to speech.

```
10 D$=CHR$(4)                          : CTRL-D FOR DOS COMMANDS
20 PRINT D$;"BRUN TEST"                : LOAD PROGRAM CREATED BY ECHO WORDS
                                       :   EDITOR
30 &0,1,2,3                            : SAY 'MY COMPUTER CAN SPEAK'
40 &"WITH","THE"                       : ALTERNATE FORM
50 &V+3, "ECHO II", VO                 : SAY 'ECHO II' LOUDER
60 &"SPEECH",S,"SYNTHESIZER"           : MAKE 'SYNTHESIZER' PLURAL
```

Listing 3. Selecting Echo Words to reproduce recorded speech.

OPTIONAL WORDS

An optional Echo Words diskette is available which contains the LPC data for 719 words in a female voice. Since the entire word is recorded in its entirety instead of broken up into phonemes, the speech quality is much better than the other two modes.

To use the recorded words, you enter the Echo Words Editor and create a list of the words you want to say from the list of recorded words. The LPC data for these words is then placed into a program which you can call from Applesoft using the ampersand (&) command. The only problem I found with Echo Words is that the sentences sound choppy. The words do not flow together as they do in natural speech. Other than this, the speech is very natural sounding and easy to understand.

Several other programs come with the Echo II, including a spelling test program and a talking typewriter. There is also a program to read and speak sequential data files. The specified file is read and spoken one line at a time. Of course, if the file contains strange, nonprintable characters, the Echo may generate some unusual sounds.

A program is also provided for aiding verbally impaired users. The program enables you to store frequently used words and phrases in a heirarchically arranged menu.

SPEECH CONTROL

The Echo II uses special control sequences to set speech parameters such as pitch, volume, and rate. The rate of speech is set to either fast or slow. The fast rate is a little difficult to understand at first, but becomes easier once you are used to it. The pitch can be set to 63 different levels, from a deep baritone up to a high, almost squeaky, voice. The volume can be set to 16 different levels, from a whisper to a shout.

DOCUMENTATION

The Echo II manuals are well written for first-time users that need to be walked through each step of the programs. However, they lack two things. There is no documentation on any of the programs except Textalker, Speakeasy, and Echo Words. A quick rundown on these programs would make another good chapter. Also, an alternative chapter for the tutorials would allow the technically sophisticated user to find the required information much more quickly than by having to read the in-depth tutorials.

A quick-reference card provides a handy reference of all Speakeasy and Textalker commands.

SUMMARY

The Echo II speech synthesizer is a very versatile speech synthesizer. You can either use the well designed standard programs or design your own programs. The program designer has a high level of control over how the speech sounds. There are several different modes in which speech is synthesized and each has its own quirks which need to be learned. On the other hand, Echo II takes very little time to get working. The extra utilities for speech and visually impaired users are very useful.

All in all, the Echo II is a useful addition to the Apple Library of expansion peripherals.

The Echo II is priced at $129.95 and Echo Words is available for $29.95 from Street Electronics Corp., 1140 Mark Ave., Carpinteria, CA 93103, telephone (805) 684-4593.

Reader Feedback

To rate this article, circle the appropriate number on the Reader Service card.

71	81	91
Excellent	Good	Fair

Second Tournament of Robots

A fire-extinguishing robot successfully defended its title as "best of the home brew" during Advanced Computer Products' second Tournament of Robots, held recently in Santa Ana, California.

Chip, a 6808-based robot, won first place by tracking down a burning object and dousing it with water.

The competition, in conjunction with a local computer club swap meet, attracted a crowd of several thousand spectators that included electronic engineers, hobbyists, computer buffs, and children. A variety of home-built and commercial robots competed in the tournament, with entries from as far away as Silicon Valley.

The Z-80 based Ropet, from San Jose's Personal Robotics Corp., took top commercial honors for builder Christopher Skottegard. The home-built second place winner was Bob Angelo's Eagle PC–based Auro. Other winners in the commercial division included Bruce Sanchez, operating RB5X from RB Robot Corp., and high school student Jordan Zommic, who demonstrated Topo from Androbot, Inc.

Photo 1. Ropet, from Personal Robotics Corp., took first place in the commercial division. Here Christopher Skottegard (right) explains the Ropet's operations to Dave Freeman.

The Tournament of Robots was first organized in 1983 to highlight the rapidly developing technology of personal robotics. Dave Freeman, president of Advanced Computer Products, Inc., initiated the semi-annual competition to enable the public to learn about robots: what they are, what they can do, and how they will soon be used. Besides letting the public see robots in action, the tournament has other aims. According to Freeman, "The contest gives designers, manufacturers, and experimentalists a chance to share their ideas and see what each other is doing. It's also unique and educational entertainment."

For more information about the next Tournament of Robots, contact Dave Freeman at PO Box 17329, Irvine, CA 92713.

Computer Vision and Ranging Systems for a Ping Pong Playing Robot

David Loewenstein
215 West 83rd St.
New York, NY 10024

This article surveys several types of vision and ranging systems with the goal of finding a scheme that would allow a machine to play ping pong. The game requires quickness, hand and eye coordination, trajectory prediction, very fast decision making skills, and is played within a restricted space. Therefore, it is conceivable that a robot could be built that combined the above traits, and was able to play ping pong.

Assuming that an intermediate level player can hit a ball at 30 MPH (44 ft./sec) and that a regulation table is nine feet long, a person or machine has 0.20 s to determine whether the ball will stay on the table. If the player determines that the ball will stay within bounds, the paddle must be moved to intersect the flight of the ball. As the paddle meets the ball, another decision must be made about where and how hard to return the ball. These last two concepts are learned by humans after many trial and error attempts. A computer could be *taught* these strategic skills, but the processing time would severely restrict the number of choices that could be evaluated.

The major tasks required to play ping pong are: the ability to predict three-dimensional motion using a sequence of two-dimensional images, and the arm control necessary to intersect the trajectory. Attention is focused here only upon the task of measuring the velocity of the ball in flight. Once this has been accomplished, the major problem will be to activate the manipulator in the remaining time. To complicate this task further, there are no human visual cues such as shading, occlusion, texture gradients, or shadows to aid the ranging process. Current state-of-the-art vision systems try to incorporate as many of these features as required for the specific task.

HUMAN VISION MODELS

Current research on computer vision is directed toward mimicking the human vision process. The following models lend themselves well to computer vision applications. The first method is mentioned by Ramesh Jain in his article, "Extraction of

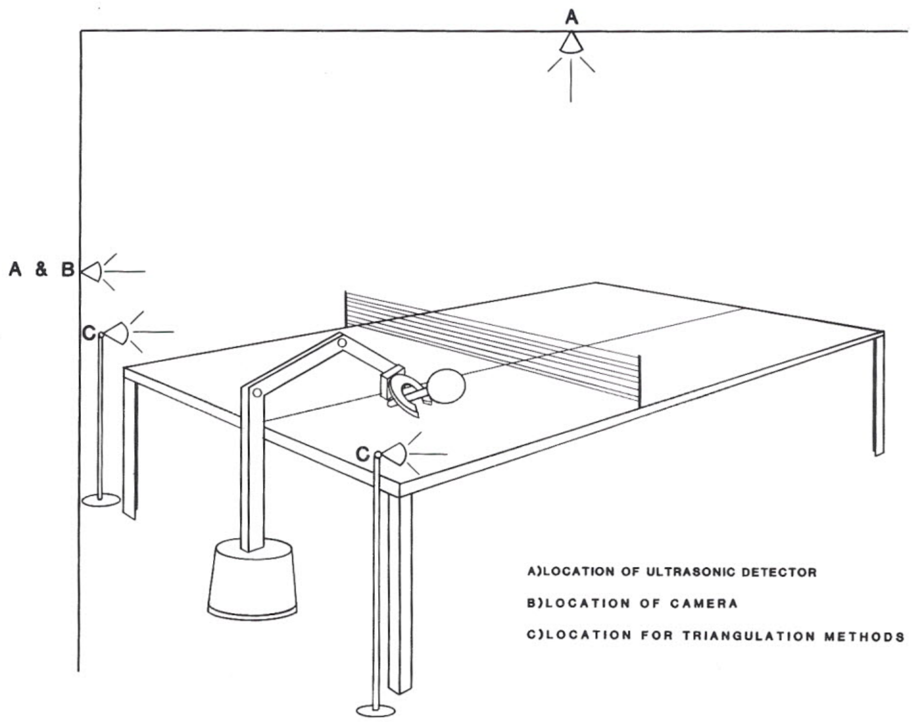

Figure 1. An idealized setting for robot ping pong. Ultrasonic detectors would be placed at location *A* to track the ball. If using a single camera system, the camera would be placed at location *B*. A dual-camera system would place cameras at both *C* locations.

Motion Information from Peripheral Processes:"

> *There are three main phases in motion perception: peripheral, attentive, and cognitive. The peripheral process identifies areas in the field of view with persistent changes from frame to frame. The attentive process focuses attention onto one of such image areas in order to investigate it in more detail. The cognitive process relates the observation derived from this subimage sequence to the knowledge about the section of the real world covered by the field of view.*

This theory has been adapted in a computer vision system called *partial token matching,* which is mentioned later. Another theory, mentioned in Shimon Ullan's article, "Analysis of Visual Motion by Biological and Computer Systems," is that vision takes place in two stages: "... one for organizing and describing the motion and another for comparing the resulting representations with similar descriptions stored in memory."

You experience the first step (recognition) when you sense an object coming toward you at very high speed. You then attempt to match the object in flight with a representation of the flying object (step two, identification). Your reactions are very different depending on whether the object is a fly or an automobile.

Obviously the first step, recognition, is much faster. This is the skill that the ranging system for ping pong will need. It assumes a priori information about the ball. In this case, the second step, identification, is eliminated. This type of system will not know how to react if an unfamiliar object is placed in its visual field.

A third term used in both human and computer vision is *optical flow analysis*. This concept depends on the field formed by points on the object surfaces as either an eye or camera moves through its environment.

The lowest level of motion detection is the intensity-based scheme, which measures motion only as a function of local changes in intensity level as a body moves through space. According to Ullman, "The intensity-based scheme is useful as a peripheral, attention-attracting *early warning system* and for separating moving objects from their background."

This technique has been used as a cloud tracking system, to extract motion from satellite data.

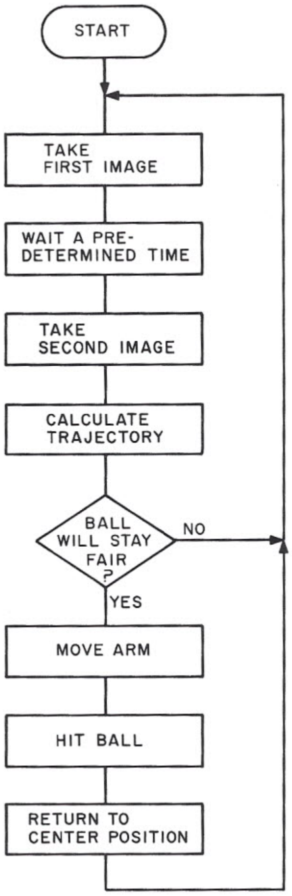

Figure 2. Sequence of operations, from the first sighting to actually returning the ping-pong ball. The entire operation, from gathering the first image to actually hitting the ball, must take place within 0.20s during a moderately-paced game.

PROBLEM DEFINITION

Most vision research is centered on objects with clearly defined boundaries. Edge detection is an important branch of motion analysis. A ping-pong ball has very clearly defined boundaries for a human, but for a machine, detecting the smooth, round, translucent edges would be an extremely difficult task. Most systems which use edge detection work well with stationary objects, but moving objects introduce noise and blurred images, making edge detection very difficult. A high contrast background would help, but probably not enough to eliminate these problems.

The flight of a ping-pong ball is a combination of rotation about a nonfixed axis and translation. At this stage in the development of computer vision, these two motions cannot be separated. However, for this application, it would not be necessary to separate these motions. What is required is the calculation of velocity from two images taken at a known time interval apart. Since there is no external force acting on the ball as it travels through the air, except air resistance (which is a predictable quantity proportional to the square of the velocity), a trajectory could be developed from these two images. Resolution is not critical, a good return could be made even if the ball is as much as one inch off center of the paddle.

STEREOPSIS

Also known as binocular vision, stereopsis is the system where two cameras are spaced a known distance apart. Points or tokens are matched to information stored in memory. The process is repeated after a known time interval has elapsed. Using this method requires two assumptions. One is the assumption that the body is rigid; the other is that the two points being examined are far from the camera relative to the distance between them and to their motion in depth. If these conditions are true, we can assume that any apparent motion between the two points is caused only as a result of the object's motion.

The apparent change in distance between two points on two successive images is compared and a triangulation algorithm is used to calculate velocity. The change in location of the points, excluding rotation, is known as disparity. This information will yield three-dimensional motion from two-dimensional information. Generally the points (tokens) which are tracked are edges, lines, and "blobs." For this application, points would have to be painted on the surface of the ball, because the edge definition is difficult to detect on a rapidly moving object. Promising research is being done on a technique called *partial token matching* where only a section of the image is compared to memory. Using the three-step model of human vision, this would be the attentive process, where attention is focused on a small area that is investigated in detail. Comparing this method to computer vision for detecting block motion only, the corner of an object would be analyzed instead of using all edges.

SINGLE-CAMERA SYSTEMS

Single-camera systems operate using the same principles as dual-camera systems. They detect motion by using disparity between successive images. However, they do

not have the problem of parallax. They are faster, since they have half the number of inputs to process, and are less likely to have problems of occlusion. A single camera is sufficient for tracking motion along the camera's axis. The process of extracting information from two, two-dimensional images is called correspondence. Correspondence is the mapping of the disparity between the two successive images of the object point.

If two points, a known distance apart, are painted on the surface of the ball, the disparity between images should yield motion information (assuming a rigid body). However, one or both points may disappear due to self-occlusion as the ball rotates. Painting several equidistant points on the surface of the ball (see figure 3), similar to the dimples on a golf ball, would allow construction of an algorithm for the ball trajectory. The vision system would need to ignore the points on the edges of the image since the ball's curvature would make them appear closer together.

Experimental results by John Roach and J. K. Aggarwal have shown that because of noise on the image, less than two views of nine points yield numerically unstable models. This would drastically increase computation time and probably eliminate this system from consideration. These experiments show that iterative solutions require 15 s to converge on a Cyber 170/175 system.

Two other promising areas for very rapid range detection are scanned light beams and ultrasonic scanners.

LASERS

These systems operate on a derivation of human intensity–based visual cues. Intensity-based theory states that humans make depth judgements based on the light reflected from an object. The closer the object, the brighter it appears. Computer vision systems follow this same theory. Motion can be calculated by comparing the output of detectors for light increments at two adjacent object positions. This scheme is called the *delayed comparison* scheme and has been proposed as a model for biological systems. Delayed comparison vision systems are fast, sensitive, and very good at separating a moving image from a stationary background. However, this method fails when the surface contains irregularities.

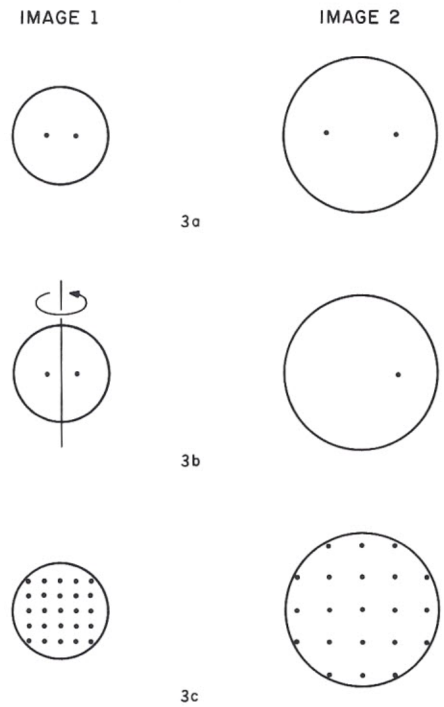

Figure 3. To help track a ball, two points could be painted on the surface. The distance between the two points is proportional to the ball's distance from the observing camera. A difficulty with using only two dots is apparent in figure 3b. Here one of the dots is occluded as the ball rotates. This problem can be overcome as in figure 3c where a matrix of equidistant points are painted on the ball.

Circle 18

This family of systems includes the Polaroid Ultrasonic Ranging System. These scanners have poor spatial resolution, generally to the limit of the 30-degree solid beam angle, and do not return signals off smooth surfaces with normals greater than 40 degrees from the source beam. Stray radiation must be absorbed so reflections do not produce erroneous signals. The positive points of these systems are price and speed. Polaroid sells its product in kit form for $165 and claims an accuracy of one percent over the entire range of 0.9 to 30 ft.

At this point, it appears unlikely that a machine using a computer vision system could be built to play ping pong at a moderate level. The main reason is the time needed to process the visual input. If other faster techniques were used, like those based on laser or ultrasonic ranging systems, it would be possible to locate the ball very quickly. Assuming that research on the laser system, which is being designed to respond in 50 ps, is successful, the limiting factor would be the speed of the manipulator arm.

A possible design would include three independent, orthogonal ranging systems, either laser or ultrasonic. The ideal strategy would be to detect the flight of the ball before it crossed the net, while it was still on your opponent's side of the table. At this point, a preliminary judgement on the trajectory could be made to start the arm in motion. All three orthogonal directions could be activated simultaneously, and each direction could drive a dedicated motor, so all the coordinate axes could be adjusted simultaneously. This would substantially reduce the time of flight because each axis would be controlled independently of the other two, and the arm would not have to wait and operate sequentially. The end points of the motion are the primary concern. The path is irrelevant as long as it does not exceed the bounds of the machine. If a program could be developed that would calculate the optimum path faster than the amount of time it saved, it would be a useful addition to the system.

Just after the ball crossed over the net, new measurements could be taken to refine the anticipated intercept point. After the ball was returned, the arm would return to a neutral position in the center of the table. This would reduce the time needed to position the arm for the next shot. Experimental tests would have to be made to determine whether the course and refined ranging sequences combined were more accurate than the one measurement method. If one measurement was sufficient, only the first detection phase on the opponent's side would be needed. The fine adjustment might only slow the task.

History has shown that when a new technology is investigated, experimentalists imitate natural models. The first flying machines used flapping wings. The current trend in computer vision is, for lack of a better model, attempting to duplicate the human vision process. However, this complicated process is far from being totally understood. Eventually, the current trend will probably reverse. Just as modern aircraft have evolved in the opposite direc-

Ping-Pong Competition

Dr. John Billingsley of Portsmouth (England) Polytechnic, has announced a new contest to stretch the mental muscles—robot ping pong. The first contest will be held in England in 1985.

To avoid endangering bystanders, the regulation-sized table tennis playing area has been reduced to a mere 50 cm wide with a frame at each end to further limit the playing space to 40 cm in height. As shown in the accompanying figure, the net in the middle of the two-meter-long table is 25 cm high.

Above the net is yet another 50 cm square frame to outlaw the unsportsrobot-like practice of lobbing the ball out of view of the opponent's sensors. The bat size must not exceed a circle of diameter 12.5 cm and the bat must not encroach inside the playing frame at the end of the table.

A simple mechanism near the top of the center frame serves the ball towards the serving robot. The robot must return the ball so that it bounces once on the opponent's playing frame. The robot opponent must in turn return the ball to bounce just once on the opposite side of the table. The point is lost if the ball strikes the playing frame or falls off the table. It is possible that there may be some very long rallies, so if the opponent successfully returns the ball 20 times, it wins the point.

The table's playing surface is three-quarters of a meter above floor level and each robot will have a 1 meter square of floor on which to stand. The means of illumination will be agreed upon with contestants as the contest draws near. The playing area will probably be illuminated by tungsten filament lamps well out of the field of view of each robot.

Robot vision is at present a costly commodity. Many of the techniques currently under development require massive computer power to analyse the optical image. The contest will, it is hoped, encourage the development of low-cost sensor techniques capable of tracking the ball, perhaps no more than half a dozen simple photocells behind a cheap camera lens.

For safety reasons, restrictions must be applied to the moving mass and power of the robot. At this early stage, it is hard to set a limit: a Puma 600 is clearly over the top, while an Armdroid or Microbot lacks the reach and speed. We will, no doubt, see some ingenious home-grown robots, perhaps with a structure of glass fiber reinforced foam.

The fastest net-skimming return from a low ball takes just under 0.5 s from bat to bounce, and has a vertical velocity on bouncing of just over two meters per second. It should be almost within the performance of the servos of any self-respecting high-speed plotter. On the other hand, a lob will give more time to respond, but may have double the vertical velocity.

Contestants should avoid some of the more obvious preconceptions. The bat need not look very much like a bat provided it does not exceed the size limitation. A curved surface could enable accuracy of control to be traded for the need for bat angle actuators. The robot need not rely on arm movement alone to strike the ball. A spring-loaded bat could be triggered to give an impact. This method would require accurate range finding and precise timing.

The problem of vision is reduced by allowing both robots to lock onto the ball before it is served. The net is transparent and so the problem is reduced to tracking, not acquisition. A robot that cannot keep its eye on the ball will deserve to lose the point. Those parts of the robot seen by its opponent must be dark in color to provide a good contrast. It may be necessary to specify a black paint that is also back to infrared light. The back of each robot should, in contrast, be flamboyant and attempt to entertain the onlookers.

If you are prepared to meet the challenge of robot ping pong, write to Dr. John Billingsley, Department of Electrical and Electronic Engineering, Portsmouth Polytechnic, Anglesea Rd, Portsmouth, ENGLAND, P01 3DJ.

tion as the early attempts at flying machines, future vision systems may have little in common with their human counterparts.

The process of trial and error has shown that mechanical devices usually perform better when they do not try to imitate biological ones. The same will no doubt happen to computer vision systems. The most likely form will be hybrids combining the best aspects of ultrasonic and laser systems, which seem to hold the future for machine vision. They are fast, comparatively easy to operate, and, as the technology improves, they will become much more accurate. The challenging task is processing the information once it leaves the vision system.

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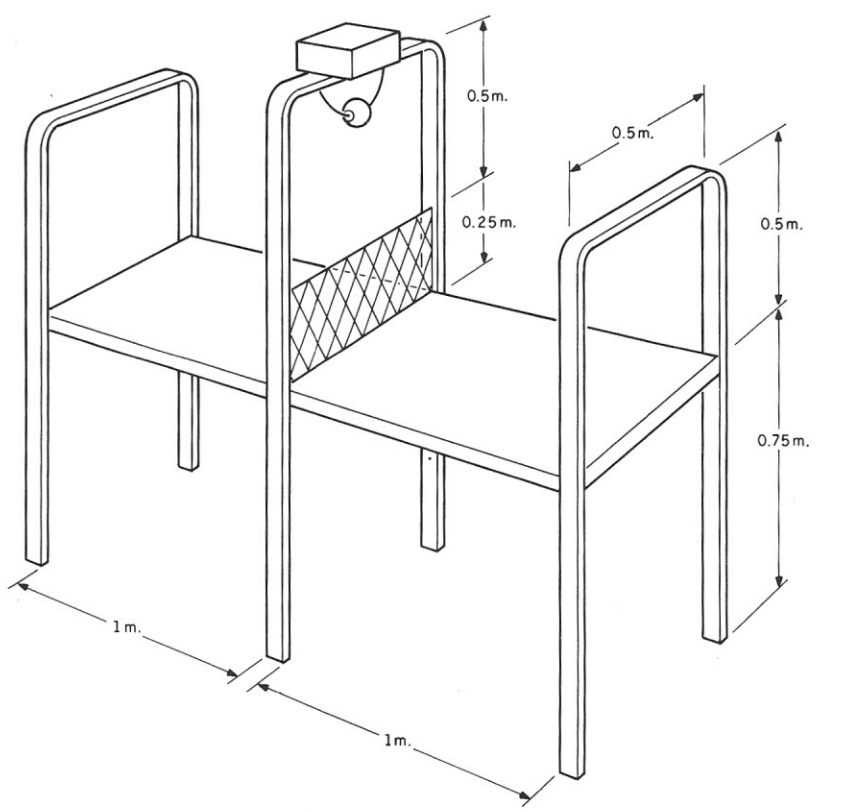

ROBOTS AND EMPLOYMENT

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Robot opponents argue passionately that the machines displace workers. Advocates counter that mechanization is necessary; without robots American industry will become uncompetitive and jobs will be lost anyway. The debate seems to generate more heat than light. Neither side seems to distinguish among various ways of implementing robotics.

Mechanization is not a new phenomenon, even though robots take mechanization to a new level of sophistication. There are precedents which offer parallels to the contemporary adoption of man-replacing machines. Two examples are particularly worthy of examination.

THE AUTOPILOT

In many ways, the device most similar to an industrial robot is the aviation autopilot. Indeed, some people feel an autopilot *is* a robot. The autopilot controls another machine (an airplane) more precisely than a human operator could. Yet, the robot has not replaced human pilots.

The reason that human pilots need not worry about being replaced by an autopilot is perhaps best expressed in the old joke about the world's first fully automated flight. Shortly after takeoff, the passengers are informed by a synthesized voice that they are part of a historic first, riding on an aircraft without human pilot. But the passengers are unnerved when the voice begins repeating over and over again, "This fully automated system is totally safe. There is no possibility of malfunction, -sibility of malfunction, -sibility of malfunction . . ."

It seems safe to predict that in applications where unanticipated situations may arise and where human safety is involved, human operators will be retained to oversee robots rather than being replaced by them. But in more general applications, where unskilled or semi-skilled workers are used in routine applications with minimal concerns about safety, the autopilot example is a poor guide.

THE ENGINE

The best parallel to the replacement of modern workers with robots may well be in the replacement of workers a generation ago by the internal combustion engine. Of course, few men were replaced by a naked engine; it was attached to some other machine. The automobile and tractor are both good analogs to examine. While technologically similar, they had vastly different effects on jobs.

Tractors displaced workers in the largest employment area in the economy of that day. When the first mass-produced tractor was introduced during World War I, agriculture employed almost as many people as all other phases of production and services combined. Within a generation, agricultural labor (including owner/producers) shrank to an almost insignificant percentage of the total labor force, and continued to shrink for another generation. Apologists for the tractor claimed it produced more jobs than it destroyed—jobs in tractor factories and dealerships, in the tire industry, in the petroleum industry, and even in the insurance industry. In retrospect, such a claim can be seen to be patently untrue. In all, more than 2.2 million paid workers were forced out between 1920 and 1940, and a total of about 8 million people left the agricultural sector. Although the tractor did not displace all of that number, it was the largest factor in that displacement, far larger than any other.

At the same time, the best estimates indicate that the tractor directly created no more than 95,000 jobs at peak production, and a figure half that may be more accurate. Indirect employment (in allied industries) was probably much smaller. Farm mechanization (with the tractor in the vanguard) contributed significantly to unemployment in the Depression era. And the legacy of its job destruction did not stop with the return of prosperity. Unskilled farm workers who fled to the cities seeking wartime work formed the core of big-city ghettos.

Other machines besides tractors used internal combustion engines. These also displaced labor. The automobile was bad news to harness makers, blacksmiths, horsebreeders, and even veterinarians. Mechanized transportation destroyed their livelihoods. Yet, for the American economy as a whole, the automobile was a net producer of new employment. Basic industries such as steel, glass, and rubber expanded measurably due to automobiles. Automobiles created new jobs in sales and repair. Entrepreneurs such as George Pepperdine made fortunes franchising new stores to serve the "aftermarket trade," and many towns and cities still have one of the Pepperdine *Whites's Auto Stores* selling auto-related items, employing local labor, and indirectly employing people at factories across the nation. In fact, the automobile created so many jobs that most economists estimate that one job in five in the United States is dependent on cars and trucks.

Robots may follow a scenario similar to that of tractors, or to that of automobiles, or they may follow their own third course. Obviously, everyone hopes for more jobs and a growing economy. But good intentions and wishful thinking will not guaran-

tee such an outcome. There are some pertinent characteristics about past mechanization, however, that can help.

OPTIONS

It seems advisable to concentrate first on consumer-oriented robot applications. A consumer robot which vacuums the living room may be technically challenging, but it would open up an incalculably large market. The developer will face the problems inherent in any new industry, but also faces the possibility of financial rewards comparable in our day to those Ford achieved with flivvers. (Admittedly, the developer today would more likely be a corporate entity than an individual.) More important—at least from society's view—the developer will create jobs and economic expansion. The consumer robot also appears likely to displace few gainfully employed workers. FICA, minimum wage, and income taxes destroyed the use of domestic servants a half-century ago.

Industrial robots, by contrast, are more like tractors. They seem destined to be net destroyers of jobs. While they may be a necessity in some highly competitive industries like the automotive industry, their overall consequences appear to be predominantly negative, not only in displacing workers, but also by encouraging further concentration of industry into still tighter oligopolies. If the day comes when there is a shortage of workers, then it would be easy enough to convert factories to robot workers—*if* consumer robots were given priority earlier.

If industrial robots develop first, it seems possible that a situation may well develop parallel to that of the 1920s and 1930s when productivity outran the consumer's purchasing ability. In order to purchase, the consumer must have disposable income. To have disposable income, he or she must be employed. Disrupt employment and markets disappear. Consumer robots seem less disruptive and more constructive.

It appears highly advisable for the robotics industry to study its potential impact on the economy and society and aim toward the most constructive areas available. There really are two reasons for such study and planning. Enlightened self-interest would suggest that a healthy economy is good for industry. Failure to proceed in a constructive manner invites external restraint—by government, unions, and consumer groups. While antitrust laws limit industry-wide combinations in restraint of trade, they do not inhibit professional associations and study groups which can study and recommend policies to member firms.

Given the magnitude of the potential impact of robots, to proceed willy-nilly without looking at the consequences of various policies would fall little short of criminal negligence. Robots can no more accept responsibility for what they do than can other machines. Honorable men and women should. Isn't that the difference between them and us?

About the Author: Bob Williams is a historian by training. While earning his Ph.D., he worked in both economic history and the history of technology. More recently, he has worked in business and computers. He continues to write both for popular journals and professional publications.

Reader Feedback

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73	83	93
Excellent	Good	Fair

Boston Computer Museum

The Boston Computer Museum is the only museum devoted exclusively to maintaining our computer heritage. Starting in 1979 as a small it is now preparing a November opening in larger quarters.

Exhibits include the MIT TX-0 computer, which was the first transistorized computer system. Completed in 1956, the computer is still in operational order. Other exhibits include pieces of the SAGE computer. Until recently this 50,000 vacuum tube computer was controlling the US/Canadian Early Bird Tracking Stations.

In addition to the larger computers, a planned exhibit will gather various microcomputers and personal computers, including an Apple I, SWTPC 6800, Sphere, Altair, and IMSAI.

The museum stresses the importance of hands-on experience. Although many of the systems could not be maintained on a continuous basis, their functions can be simulated on newer systems. The museum staff has taken great care to ensure the simulations are identical with the original displays and software.

On your next trip to Boston, make sure you stop by the museum for a look at the forebears of today's computer technology. To find out more about the museum, contact: Gwen Bell, The Computer Museum, 300 Congress St, Boston, MA 02210, telephone (617) 426-2800.

Circle 14

ANGLES AND BRADS

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In this age of microcomputers and robots, I think that we should reexamine the way that we measure angles.

Several thousand years ago, ancient mathematicians decided that a circle should be divided into 360 parts, called degrees. Well, it was a good idea, for humans. Even today, most people still measure angles in degrees. Scientists, however, created their own angle measurements, radians, because it simplified their formulae. More recently, civil engineers came up with the idea of dividing a quadrant into 100 parts called grads to make their job easier, but that idea doesn't seem to have ever really caught on.

I propose that we in the field of computer-controlled robots start measuring angles in brads. What are brads? Why, binary radians of course. We are all familiar by now with binary arithmetic, and most of us are using computers that process data in eight-bit bytes. In this environment, what could be more natural than to divide a circle into 256 parts? A brad is exactly 1/256th of a circle.

Measuring angles in brads has many advantages for processing angle data and trigonometric angle functions. First of all, let's adopt a format for angle data in which the weights (in degrees) for each of the eight bits in a byte are determined as shown in Figure 1.

In hexadecimal notation (indicated by the "$" prefix):

\$80 = 180 degrees = 128 brads
\$40 = 90 degrees = 64 brads
\$20 = 45 degrees = 32 brads

etc.

\$01 = 1.40625 degrees = 1 brad

The following example shows one of the problems that arises when summing two angles whose result is greater than 360 degrees.

Decimal	Hexadecimal
270	\$C0
+180	+\$80
450	\$40

Using decimal degrees, we have to subtract 360 to get the answer we really want (90 degrees). Using brads, expressed in an eight-bit byte, we get the required answer just by ignoring the carry.

As a second example, suppose we wish to multiply an angle by a constant scale factor, say 11 times 135 degrees.

Decimal	Hexadecimal
135	\$60
x 11	\$0B
1485	\$20

Using decimal degrees, we have to subtract 1440 to get the answer we really want (45 degrees). Using brads, we again get the right answer simply by ignoring all carries beyond eight bits.

When dealing with negative angles, an angle byte in brads can be treated as a two's complement number. For example:

Decimal	Hexadecimal
135	\$60
−225	−\$A0
−90	\$C0

The correct answer in this case is either −90 or +270 degrees. This appears directly in brads by ignoring the borrows beyond eight bits.

To determine the negative of an angle, simply take the two's complement. To find the supplement of an angle in brads, subtract it from \$80. To determine the complement of an angle, subtract it from \$40. See the advantages of measuring angles in brads?

TRIGONOMETRIC COMPUTATIONS

Assuming you are now convinced that measuring angles in brads can simplify your basic calculations, the next step is determining sine and cosine. The simplest, most direct, and fastest method is table lookup. Since we are working with eight-bit data, let's choose the two's complement format shown in Figure 2 for the table entries. Interestingly, this format makes the sine of +90 degrees and −90 degrees identical to the angle:

sin(90) = sin(\$40) = \$40 = 1
sin(−90) = sin(\$C0) = \$C0 = -1

Although a shortened sine/cosine table covering only one quadrant could be used, I recommend that a full 256-byte page of

BIT	7	6	5	4	3	2	1	0
WEIGHT	180	90	45	22.5	11.25	5.625	2.8125	1.40625

Figure 1. When using brads, the angle values are all stored within an 8-bit byte. The numbers under each bit indicate the associated weight in degrees.

BIT	7	6	5	4	3	2	1	0
WEIGHT	SIGN	1	1/2	1/4	1/8	1/16	1/32	1/64

BINARY POINT

Figure 2. The format for sine and cosine values is chosen to fit within a single 8-bit byte. The high bit is reserved for sign and the binary point is placed between bits 5 and 6. This allows us to represent a number with an accuracy of 6 binary digits.

memory be allocated for storing a full four-quadrant table. This technique avoids wasting time juggling signs or angle sectors just to look up the sine or cosine of an angle. The eight-bit sine table is shown in Table 1.

The table entries have been rounded off the nearest multiple of 1/64 which gives a root-mean-square error of less than 0.25 percent of full scale. This accuracy is sufficient for most engineering work.

The same table can be used to look up cosines by taking advantage of the identity:

cos(a) = sin(a + $40)

To determine the cosine, first add $40 (90 degrees) to the angle and then use the same procedure as for looking up the sine.

An example of a fast sine/cosine lookup routine is included in Listing 1. Also included in Listing 1 is a fast four-quadrant signed multiplier routine. With these routines, a high-speed, polar-to-rectangular coordinate conversion (PRC) becomes a straightforward operation.

Applying the polar-to-rectangular routine twice permits a high-speed spherical-to-rectangular coordinate conversion (as shown in Figure 3). For an elevation angle (e) and azimuth angle (a):

(r cos(e),z) = PRC(r,e)
and
(x,y) = PRC(r cos(e), a)

A rectangular-to-polar coordinate conversion (RPC) is not as straightforward as the PRC operation, but it can still be made quite efficient. To calculate the polar angle (a) from the rectangular coordinate pair (x,y), the most direct and fastest method is again to use a table lookup routine. We could first divide to get tan(a) = y/x. Then we could look in an arctangent table to get the angle (a). However, the tangent function goes to infinity at ±90 degrees. Therefore, we cannot store a full four-quadrant arctangent table as we did for the sine table. Instead, we must first find in which 45-degree octant the (x,y) pair lies and then use an arctangent table covering only 0 to 45 degrees.

To achieve an accuracy of better than 1 brad (1.40625 degrees), we will need at least six binary places in the tangent ratio. Let's adopt the same format for tangent data as for sine/cosine data, except in this case the sign bit will always be 0 (positive). Table 2 contains the arctangent lookup table in hexadecimal format.

TABLE 1

Address Offset	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F
00	00	02	03	05	06	08	09	0B	0C	0E	10	11	13	14	16	17
10	18	1A	1B	1D	1E	20	21	22	24	25	26	27	29	2A	2B	2C
20	2D	2E	2F	30	31	32	33	34	35	36	37	38	38	39	3A	3B
30	3B	3C	3C	3D	3D	3E	3E	3E	3F	3F	3F	40	40	40	40	40
40	40	40	40	40	40	40	3F	3F	3F	3E	3E	3E	3D	3D	3C	3C
50	3B	3B	3A	39	38	38	37	36	35	34	33	32	31	30	2F	2E
60	2D	2C	2B	2A	29	27	26	25	24	22	21	20	1E	1D	1B	1A
70	18	17	16	14	13	11	10	0E	0C	0B	09	08	06	05	03	02
80	00	FE	FD	FB	FA	F8	F7	F5	F4	F2	F0	EF	ED	EC	EA	E9
90	E8	E6	E5	E3	E2	E0	DF	DE	DC	DB	DA	D9	D7	D6	D5	D4
A0	D3	D2	D1	D0	CF	CE	CD	CC	CB	CA	C9	C8	C8	C7	C6	C5
B0	C5	C4	C4	C3	C3	C2	C2	C2	C1	C1	C1	C0	C0	C0	C0	C0
C0	C0	C0	C0	C0	C0	C0	C1	C1	C1	C2	C2	C2	C3	C3	C4	C4
D0	C5	C5	C6	C7	C8	C8	C9	CA	CB	CC	CD	CE	CF	D0	D1	D2
E0	D3	D4	D5	D6	D7	D9	DA	DB	DC	DE	DF	E0	E2	E3	E5	E6
F0	E8	E9	EA	EC	ED	EF	F0	F2	F4	F5	F7	F8	FA	FB	FD	FE

(r cos(e),z) = PRC(r,e)   (x,y) = PRC(r cos(e),a)

Figure 3. The polar-to-rectangular conversion can be performed twice which results in a spherical-to-rectangular coordinate conversion. Here the elevation angle is represented by *e*, the azimuth angle by *a*, and the rectangular coordinates by *xyz*.

Listing 1.

```
        ORG SCRATCH
;
TEMP    RMB R           ;Reserve 4 bytes on Page 0
;
        ORG TRIG
;
PRC     STD TEMP        ;Save A,B = r,a = radius, angle
        BSR MULSIN      ;AB = r sin (a), unrounded
        BSR ROUND       ;A = r sin(a), rounded
        STAA TEMP+2     ;Save r sin(a)
        LDD TEMP        ;A,B = r,a
        BSR MULCOS      ;AB = R cos(a), unrounded
        BSR ROUND       ;A = r cos(a), rounded
        LDAB TEMP+2     ;B = r sin(a), rounded
        RTS             ;Return A,B = x,y
;
MULCOS  ADDB #$50       ;Add 90 degrees to angle
;
MULSIN  LDX #SINTAB     ;Point to table of sines
        ABX             ;Offset into table
        LDAB 0,X        ;B=sine/cosine of angle
;
```

Listing 1 continued.

After looking up a polar angle in this table, we must take the 90-degree complement of the angle if it lies in an even-numbered octant. We must also take the 180-degree supplement of the angle if it lies in an even-numbered quadrant, and negate the angle if it lies in the lower semicircle.

Once we have determined the polar angle (a), we can get the two-dimensional radius (r) with two signed multiplications and one addition:

$$r = x\ \cos(a) + y\ \sin(a)$$

As before, a three-dimensional rectangular-to-spherical coordinate conversion is equivalent to two sequential RPC operations.

Assembly language programs to perform all of these operations are given in Listing 1. They are designed to use the instruction set for the Motorola 6801 microprocessor and require only 147 bytes of program memory plus four bytes of scratchpad memory. An additional 321 bytes of memory must be allocated for storing the sine and arctangent tables. The execution times for the utility routines are shown in Table 3.

These execution times are impressively short, even by assembly language standards, due in large part to the shortcuts made possible by scaling the angles in brads. In addition, the memory requirements are quite modest, which makes it feasible to perform the computations in real time on board a mobile robot.

I chose to write these programs for the Motorola 6801 microprocessor for two reasons—first of all, because it is a microprocessor highly suited for robotic applications, and secondly because I have been using the Virtual Devices 6801 upgrade for Heath's HERO-1 robot. The 1.2288 MHz clock rate was chosen to simplify serial communications at either 300 or 1200 bps (1.2288 MHz is 4096 times 300 bps). Real-time execution speeds are also quite possible for other microprocessor chips.

COMPATIBLE ACTUATORS AND SENSORS

Controlling and sensing angles in brads are potentially very compatible with either stepping motor actuators or DC servo actuators.

Stepping motors are open-loop actuators, but they are quite accurate as long

Listing 1 continued.

```
M4Q     STD TEMP        ;Save entry A,B factors
        MUL             ;AB=A*B
        TST TEMP        ;Test sign of A
        BPL M4Q1        ;Branch if positive
        SUBA TEMP+1     ;Subtract B*256 if A was < 0
;
M4Q1    TST TEMP+1      ;Test sign of B
        BPL M4Q2        ;Branch if positive
        SUBA TEMP       ;Subtract A*256 if B was < 0
;
M4Q2    RTS             ;Return AB = signed product
;
ROUND   ASLD            ;Shift 16-bit product
        ASLD            ;  two places left
        TSTB            ;Test highest bit of B
        BPL ROUND1      ;Branch if B < $80
        INCA            ;Round 8-bit product upward
;
ROUND1  RTS             ;Return A = 8-bit signed product
;
RPC     STD TEMP        ;Save A = x, B=y
        TSTB            ;Test sign of y
        BPL RPC1        ;Branch if upper semicircle
        NEGB            ;B=¦y¦
;
RPC1    ROL TEMP+2      ;Save semicircle indicator
        TSTA            ;Test sign of x
        BPL RPC2        ;Branch if right quadrant
        NEGA            ;A=¦x¦
;
RPC2    ROL TEMP+2      ;Save quadrant indicator
        CBA             ;Compare ¦x¦ to ¦y¦
        BCC RPC3        ;Branch if ¦y¦ smaller
        PSHB            ;Swap so that
        TAB             ;  B = smaller
        PULA            ;  A = larger
;
RPC3    ROL TEMP+2      ;Save octant indicator
        TSTA            ;Test for A=B=0
        BEQ RPC7        ;If so, return (r,a)=0,0
        BSR DIV         ;B=smaller/larger
        LDX #ATNTAB     ;Point to table of arctangents
        ABX             ;Offset into table
        LDAB 0,X        ;B = angle (0-45 deg)
        LDAA TEMP+2     ;A = 3-bit sector indicator
        LSRA            ;Test octant indicator
        BCC RPC4        ;Branch if odd-numbered octant
        SUBB #$40       ;Convert angle to
        NEGB            ;  90-deg complement
;
```

Listing 1 continued.

Listing 1 continued.

```
RPC4    LSRA            ;Test quadrant indicator
        BCC RPC5        ;Branch if odd-numbered quadrant
        SUBB #$80       ;Convert angle to
        NEGB            ;  180-deg supplement
;
RPC5    LSRA            ;Test semicircle indicator
        BCC RPC6        ;Branch if upper semicircle
        NEGB            ;Convert to negative angle
;
RPC6    LDAA TEMP+1     ;A = y
        STAB TEMP+1     ;Save B = a = angle
        BSR MULSIN      ;AB = y sin(a)
        STD TEMP+2      ;Save y = sin(a)
        LDD TEMP        ;A=x, B=a
        BSR MULCOS      ;AB = x cos(a)
        ADDD TEMP+2     ;AB = radius, unrounded
        BSR ROUND       ;A = radius, rounded
        LDAB TEMP+1     ;B = angle
;
RPC7    RTS             ;Return A=r, B=a
;
DIV     STAA TEMP+3     ;Save A = larger = divisor > 0
        TBA             ;A = smaller = numerator
        LDAB #3         ;Preset quotient for 7 shifts
        LSRA            ;Preshift numerator right
;
DIV1    ROLA            ;Shift numerator left
        CMPA TEMP+3     ;Compare to divisor
        BCS DIV2        ;Branch if numerator < divisor
        SUBA TEMP+3     ;Subtract divisor from numerator
;
DIV2    ROLB            ;Insert quotient bit (inverted)
        BCC DIV1        ;Repeat if < 7 bits in quotient
        ASLA            ;Shift and compare to
        CMPA TEMP+3     ;  see if next bit would = 1
        BCS DIV3        ;Branch if next bit would = 0
        DECB            ;Round complement downward
;
DIV3    COMB            ;Take 1's complement
        RTS             ;Return B = quotient
;
SINTAB  RMB 256         ;Store sine table here
;
ATNTAB  RMB 65          ;Store arctangent table here
;
        END
```

as they are not loaded so heavily that they miss a stepping pulse. They are generally designed with a number of steps per revolution equal to some multiple of four, although I don't know of any designed for 256 steps per revolution or submultiples thereof. Why isn't a 256 step-per-revolution stepping motor available? Probably because no one ever asked for it before. Once the component manufacturers get the word, they might make life easier for us. Until then, we will have to waste time scaling our angle data to match their motors.

DC servomotors achieve closed-loop control by means of feedback from shaft-driven potentiometers or digitizers. Analog potentiometers are good for only about one to three percent accuracy. Shaft digitizers are typically used to achieve higher accuracies.

Figure 4 shows a shaft digitizer graduated in brads. The dark areas represent ones and the light areas zeroes. This type of shaft digitizer is available now, but I don't think the potential simplicity of the associated angle data processing has been recognized.

The shaft digitizer in Figure 4 uses an eight-bit Grey code which has a one-to-one correspondence to an eight-bit binary code with the added property that only one bit can change from one number to the next. Table 4 shows the associated angle, Grey code, and binary code values.

The most significant bit is the same for both codes. Each of the other Grey code bits is a 0 if the corresponding binary bit and its more significant neighbor are alike, or a 1 if they are different. Conversely, each binary bit is a 0 if the corresponding Grey bit and all of its more significant bits have even parity, or a 1 if they have odd parity.

If our sensed angle data is in Grey code (which is desirable to avoid ambiguous readings), we don't need to perform a Grey-to-binary code conversion, we simply need to rearrange the entries in our sine and arctangent tables. Having done this, we can use the same lookup routines as before.

EXTENSIONS FOR HIGHER ACCURACY

The techniques described here can be extended, if necessary, to achieve better than eight-bit accuracy. There is a price to be paid for higher accuracy, however. We may have to use more costly multispeed servos, and data processing speeds will almost certainly be slower. We should be very sure that higher accuracy is really necessary before attempting to achieve it.

Doubling or quadrupling the size of the sine and arctangent tables to get another one or two bits of accuracy is probably within reason. To get double-precision (16 bit) accuracy, however, these tables would consume more than the entire 64 Kbytes of memory available on most microcom-

TABLE 2

Address Offset	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F
00	00	01	01	02	03	03	04	04	05	06	06	07	08	08	09	09
10	0A	0B	0B	0C	0C	0D	0D	0E	0F	0F	10	10	11	11	12	12
20	13	13	14	14	15	15	16	16	17	17	18	18	19	19	19	1A
30	1A	1B	1B	1B	1C	1C	1D	1D	1D	1E	1E	1E	1F	1F	1F	20
40	20															

TABLE 3

Routine	Function	Time
MULSIN	Multiply by the sine of an angle	41μs
MULCOS	Multiply by the cosine of an angle	42μs
M4Q	Four-quadrant signed multiply, unrounded	33μs
ROUND	Scale and round-off after multiplying	15μs
DIV	Division to get tangent function	138μs
PRC	Polar-to-rectangular conversion	147μs
RPC	Rectangular-to-polar conversion	327μs

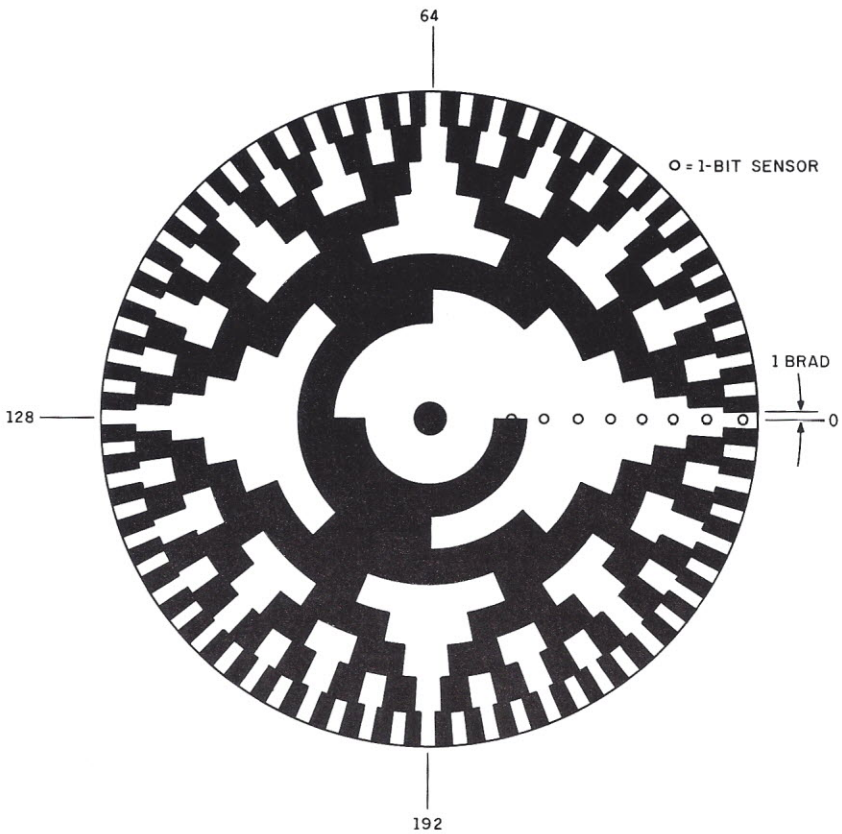

Figure 4. A standard 8-bit Grey-Code shaft digitizer is already graduated in brads.

TABLE 5

$$F(x) = x \times (A + x^2 \times (B + x^2 \times (C + x^2 \times (D + x^2 \times E))))$$

	Sine X	Arctangent X
A	$6488	$28BD
B	$D6A9	$F28D
C	$0516	$0750
D	$FFB9	$FC92
E	—	$00D4

puters. Clearly, in this case, we must fall back on power series computation to determine the trigonometric functions. Aha! you say. If we use power series computation, the angles have to be in radians, don't they? Well, no. All we have to do is adjust the coefficients in the power series to scale the angles in brads.

Both the sine function and the arctangent function can be computed with double precision using a power series of the form shown in Table 5. Only the first four terms are needed for the sine function to achieve an accuracy better than 2^{-14} over the range $x = -64$ to $+64$ brads. All five terms are needed for the arctangent function to achieve accuracy better than 2^{18} brads over the range $x = -1$ to $+1$. Suitable 16-bit coefficients to be used in each case are given in Table 5.

TABLE 4

Angle	Grey Code	Binary Code
0	00000000	00000000
1	00000001	00000001
2	00000011	00000010
3	00000010	00000011
4	00000110	00000100
5	00000111	00000101
6	00000101	00000110
7	00000100	00000111
8	00001100	00001000
etc		
255	10000000	11111111

Of course, we will need a double precision multiplier to do the power series computations and we will have to keep track of the proper sector for the angles being processed.

Incidentally, extending the angle data to 16-bit accuracy would pose an interesting question. What should we call an angle increment equal to 1/256th of a brad? The name millibrad just doesn't fit. Can anyone think of a good name that means "one 256th of a brad?"

About the Author

Mr. Ballard is an electrical engineer with the Defense Systems Group of TRW, Inc. He works principally with communication and signal processing systems for military applications, but he is also actively engaged in experimental robotics.

ROBOTS 8 EXPOSITION AND CONFERENCE

WALTER BANKS, CONSULTING EDITOR

Robotics International of the Society of Manufacturing Engineers held their eighth annual Robotics show in Detroit from June 4th through 7th.

The Robots exposition and conference is the largest annual robotics show in the United States. It emphasizes the role of robots in the production environment. This year's show demonstrated a tremendous maturation of the robotics field since Robots 7, held last year in Chicago. The theme for Robots 8 was "Merging Technologies" and emphasized how various technologies are being combined to meet industry's expanding requirements.

EDUCATION AND SMARTS

Two items separated this year's show from last year's: education and sensors. I saw an obvious increase in the number of exhibitors concerned with robot education. Last year, only two or three booths were devoted to educational topics. This year, at least 14 booths were devoted to educational robots, robot courses, and universities and colleges with robot programs. The conference session discussing *Education and Training Efforts in Robotics* was also well attended.

A large number of show attendees were from educational institutions in both Canada and the U.S. Educators everywhere are trying to meet the demand for robotics programs. They were attending to find out what is happening in the field and what new skills people in the robotics field are going to need. Most educators that I talked to were in the process of setting up small robotics laboratories with a number of microcomputer-controlled robot arms. The course material they were developing consisted of a wide variety of interdisciplinary topics ranging from basic electronic and mechanical engineering to computer programming and logic courses.

While walking about the exhibit floor, I found that the booths with educational information were always crowded. Amatrol, Inc. was demonstrating its servocontrolled hydraulic and pneumatic training robots as well as a DC servomotor robot. Feedback, Inc. was demonstrating its robotic arms and courseware. Feedback has a variety of courseware ranging from simple electronic or mechanical sessions through complete hydraulic robot design. Heathkit was displaying the HERO 1 as well as a variety of electronic trainers and courses. PREP, Inc. was showing its robotics training program and literature which is imported from Israel.

Colleges, universities, and vocational-technical schools were also well represented on the exhibit floor. The Ben Franklin Partnership (BFP) was discussing its Advanced Technology Centers which provide research and development facilities, education training, and entrepreneurial assistance. The partnership includes Carnegie-Mellon University, Penn State, and the University City Science Center in Philadelphia. Several regional colleges and vocational-technical schools also had booths and were happy to discuss ongoing robot work. ►

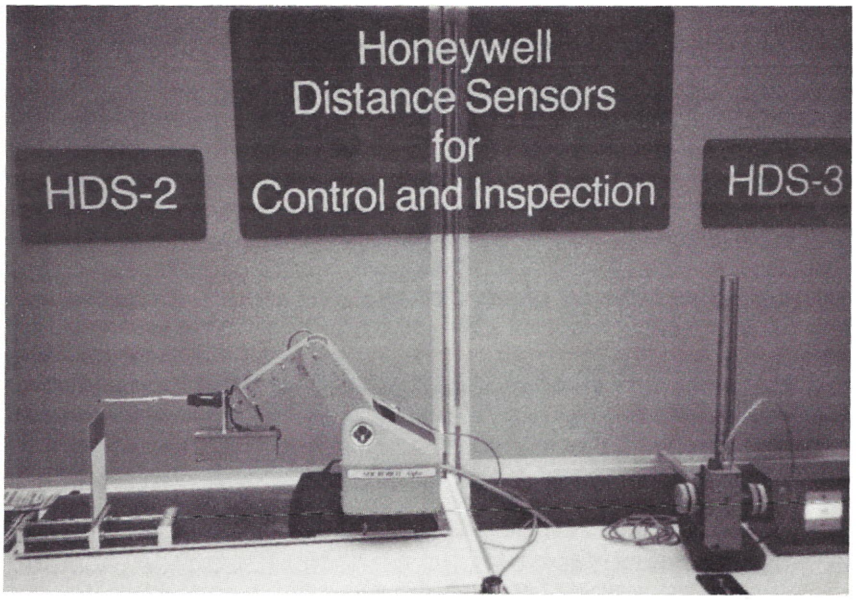

Photo 1. This photo represents two of the major themes evident at the Robots 8 Exposition and Conference. Smaller, light-industrial robot arms are being used for testing and light assembly. The other theme represented here is the increased use of sensory feedback. Although this particular setup is just a demonstration, it shows how precise control of feedback information can result in increased system performance.

Robots have also become much more aware of their surroundings during the past year. Robot vision has become a reality. The complex problems of processing the large amounts of data produced by a vision system into meaningful results in real time appear to have been generally solved. Companies such as Cognex, Diffracto, Itran Corp., Image Data Systems, L.N.K. Corp., Pattern Processing Technologies, and Object Recognition Systems all had automated vision inspection systems. Inspection systems can function as stand-alone quality assurance systems or as part of a much larger production automation system. Vision can be used to provide feedback information in a robotic arm control system. A number of systems use structured light to gain some three-dimensional data from a single camera.

The second sense which is receiving a lot of attention is touch. Manufacturers demonstrating robot tactile systems included Robohand, Inc., The Lord Corporation, and Transensory Devices, Inc. Several of the exhibiting educational institutions were also discussing work being done with tactile sensors.

Combining the two senses of vision and touch promises to produce a robot capable of handling most of today's manufacturing needs. At that point, only the final integration of intelligent, adaptable software will be necessary to create robot systems capable of any assembly task. Although the robot industry is still some years from providing the necessary software solution, the first steps toward integrated vision and tactile sensing systems will most likely appear at next year's Robots show.

THE SHRINKING WORLD OF ROBOTS

In addition to becoming more aware of their surroundings, robots are also becoming smaller. The industry is starting to consider small, light robot arms as serious design tools.

The Microbot series of Teachmovers and industrial Alpha robots have moved from the educational sphere to the light-industrial sphere. Although these machines cannot move heavy objects like their bigger brothers, they do provide an inexpensive, accurate, repeatable robot arm. One of the many applications seeing increasing use of light-industrial arms is part testing. The small arms can manipulate probes, or arrange parts in the correct orientation for inspection. As the *tabletop* arms become more accurate and able to lift greater weights, more and more applications will become apparent.

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PART OF THE BEGINNING

Ron Johnson
Senior Educational Media Designer
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Raymond GA Cote
Robotics Age Magazine

"Be part of the beginning!" trumpeted the promotional literature. The brochures enticed us to come to Albuquerque, New Mexico and experience the start of the new robotics age. The International Personal Robot Congress promised to introduce the next generation of robot engineering.

The idea for a personal robot show was the brainchild of Joe Bosworth, President of RB Robot Corp. Under Joe's guiding force, a steering committee was formed and informally met to lay the groundwork at the Consumer Electronics Show in Las Vegas in early 1983.

The steering committee consisted of: Joe Bosworth, Chairman; Douglas Bonham, Director of Educational Marketing and Development for Heath Co.; Skip Steveley, President of Androbot; Russ Eberhart of Computer Junction; Nelson Winkless of Excalibur Technology; and Sharon Smith, Director of IPRC 84. Although the committee's choice of Albuquerque, New Mexico for the show site placed the congress off the beaten path (just try and find a straight flight to Albuquerque), the city itself lent much to the show's attraction. How unusual it was to fly into a city without first having to descend through a cloud of smog. In addition, the smaller city and open spaces provided a slower-moving show with time to actually sit and talk with exhibitors and attendees, instead of continually racing through crowds looking for one or two special exhibits.

Perhaps, too, the steering committee chose Albuquerque for nostalgic reasons. Perhaps they wished to influence the future by situating the IPRC on the site of the first MITS/Altair Computer Conference. Or maybe the choice was due to the phrase found on every state license plate, "New Mexico, Land of Enchantment."

Thursday, exhibitor setup day, provided a scene of frenetic activity on the exhibit floor. Amongst all the hustle and bustle of setting up, you noticed cars, vans, and trucks arriving bearing license plates from such states as California, South Dakota, Rhode Island, Iowa, Illinois, Colorado, and others. Each time a new exhibitor pulled into the convention center to unload, the other exhibitors would gather around, eager to see what new creation was being unveiled. By late afternoon, all the drapes had been hung; the carpeting laid; and the booths properly arranged. The stage was set for the opening of the First International Personal Robot Congress.

On Thursday evening there was an informal reception for approximately 40 guest speakers at the convention center. Here, the exhibitors and the speakers had a chance to meet and discuss the latest developments in the field of personal robots. Vision systems, tactile sensors, mobility, memory, and robot usage were the topics most widely discussed. Many different ideas and points of view were exchanged between robot enthusiasts and robot experts.

OPENING CEREMONIES

Early Friday, the First International Personal Robot Congress was officially opened with a ribbon cutting ceremony outside the convention center. Albuquerque Mayor Harry Kinney and several robots did the honors. Everyone then proceeded into the convention center where Joe Bosworth introduced Isaac Asimov, who—live from New York City via telecommunications satellite—gave the keynote address. Asimov gave a very interesting presentation on robots—past, present, and future. He believes that robots and humans can, and will, coexist, but humans will still be the master. Asimov also coined a new term, *helpmates*, to describe how he sees robots fitting into our society.

Two other featured speakers, Joseph Engelberger (often called the father of industrial robots) and Nolan Bushnell (of Androbot fame) presented two different views on personal robots. Bushnell felt that personal robots must be low-cost and entertaining while Engleberger took the position that personal robots could be expensive as long as they could perform useful tasks.

Up until the moment the front doors opened, there was a fair bit of uncertainty surrounding the number of attendees expected. However, although only 200 attendees were registered for actual technical sessions, and 1500 people registered for the exhibitions, it seems that this was the "right" group of people. The attendees came from all walks of life. There were robot hobbyists, educators, software developers, and the just plain curious. Not only was Albuquerque and the state of New Mexico well represented, but also a major portion of the other 49 states, plus numerous foreign countries. It was truly an international congress.

All the exhibitors were overwhelmed by the interest shown by the media, both local and national. Every time you wandered about the convention floor or into the conference rooms, you saw television cameras and lights, interviewers after the latest news stories and photographers recording all the events. No one had anticipated this much media coverage.

Not only were the commercial exhibitors kept busy answering questions and demonstrating products, the *Personal Robot Developers* (experimentalists and entrepreneurs) were busy fielding questions and showing how their various robots worked and what they could do. The pace was busy all day and when the exhibition hall closed for the evening, everyone knew the congress was a success.

Saturday was much the same, with technical sessions in the morning and the exhibit hall open in the afternoon. Again, the response was good from both the public and the media. In contrast to Friday, where

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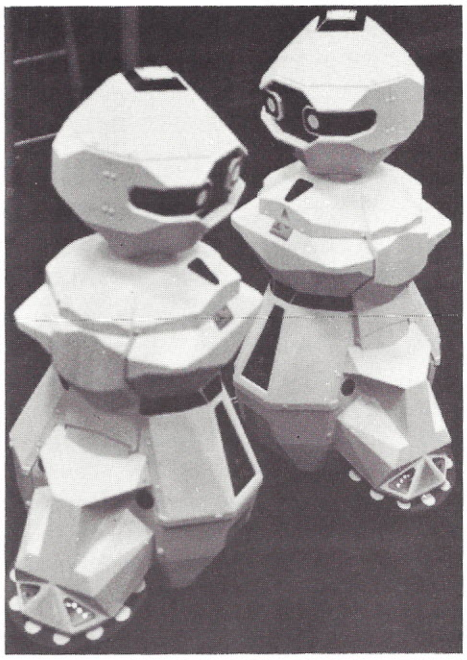

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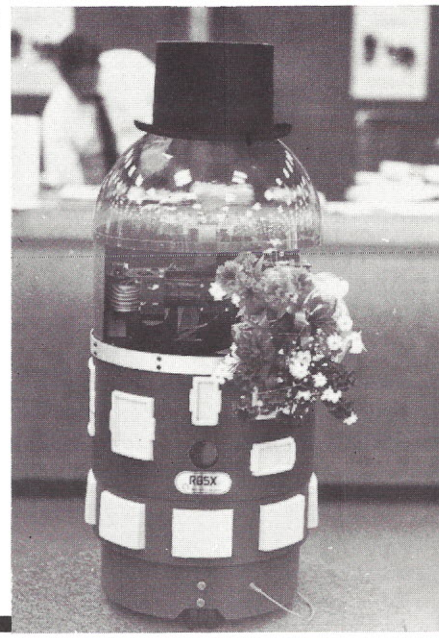

Photo 1. Androbot's Topos performed a choreographed song and dance about the booth. (Photo by Stan Miastkowski.)

Photo 2. Heath's Myron Kukla spent some time instructing HERO 1 in the finer points of show demonstrations. (Photo by Stan Miastkowski.)

Photo 3. RB5X presented passers-by with a cheery greeting and a bouquet. (Photo by Stan Miastkowski.)

Photo 4. The Robotic Industries Association was speaking with attendees and exhibitors about their decision to allow personal and educational robot manufacters to join. (Photo by Stan Miastkowski.)

Photo 5. Spectron Instruments demonstrated several of the small robot systems including this vacuum-carrying robot base. Spectron also announced their vision system for tracking objects such as Ping-Pong balls. (Photo by Stan Miastkowski.)

Photo 6. Fetal I, constructed by Bill La, is a three-wheeled vehicle capable of moving in any direction. A later prototype, Fetal II, was presented a Golden Droid award. (Photo by Stan Miastkowski.)

Photo 7. The EZ Mower by Reza Falamak received a Golden Droid award for most useful robot. At present, the machine is radio controlled. The chain gear around the outside of the mower provides directional control for the four wheels. (Photo by Richard J. Carson.)

Ron Johnson is a Senior Educational Media Designer for Heath Company. He has written several books and articles on robotics.

most of the attendees had technical backgrounds, Saturday saw many families in attendance. Many of the exhibitors were amazed by the technical questions and interest shown by the younger generation. However, this should come as no surprise as they have grown up with this computer technology.

Sunday was the day everyone had been waiting for, the awards brunch. Nelson Winkless, the official historian for IPRC, acted as master of ceremonies. After his opening remarks and thanks to the many behind-the-scenes personnel, Nels got down to the most important part of the program, the presentation of the *Golden Droid* awards.

The *Golden Droid* awards were presented in three categories: the *most entertaining* going to Bruce Taylor for his robot Henry; the *most useful* being presented to Reza Falamak and his EZ Mower Robot; and the *open* award going to Bill H. T. La for his Fetal II. After the picture-taking and congratulations were over, it was back to the exhibition hall for the final afternoon of the show. Although Sunday's attendance was somewhat less than the two previous days, the enthusiasm was still evident.

EXHIBITORS

Approximately 25 exhibitors attended the congress. Although no companies announced any major new products, this was the first time that many of the attendees had a chance to actually see and use many of the products.

The "Big Three," Androbot, Heath, and RB, all had impressive exhibits with dancing and singing robots. Androbot demonstrated how their yet-to-be-released BOB robot could be sent to the kitchen for a six-pack of beer. Heath showed how the HERO 1 can now be controlled with the new radio communications option. RB Robots demonstrated the RB5X and the ability to program it using the Excalibur Technologies natural-language system. RB shared their booth space with one of their distributers, National Robotic Systems, who demonstrated a revolving Polaroid ultrasonic ranging system which can be placed on top of the RB5X.

One of the most impressive aspects of the show was that all the remotely controlled robots managed to work and not interfere with each other. At one point, up to 12 robots were wandering around the exhibit hall under radio or infrared con-

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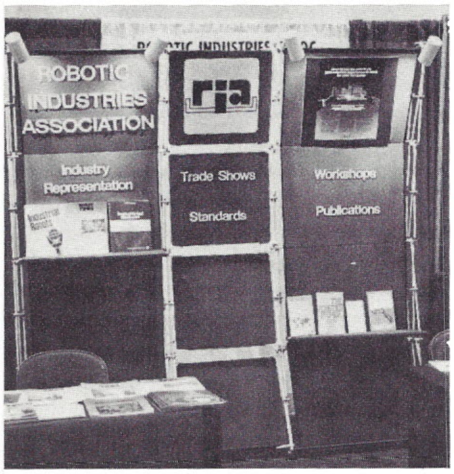

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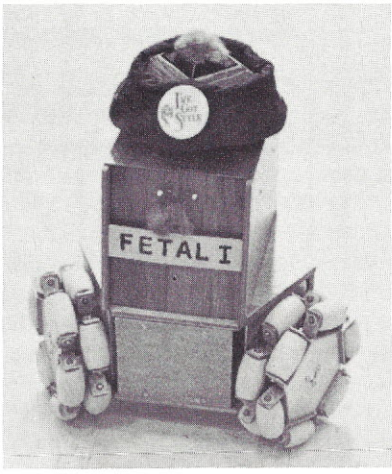

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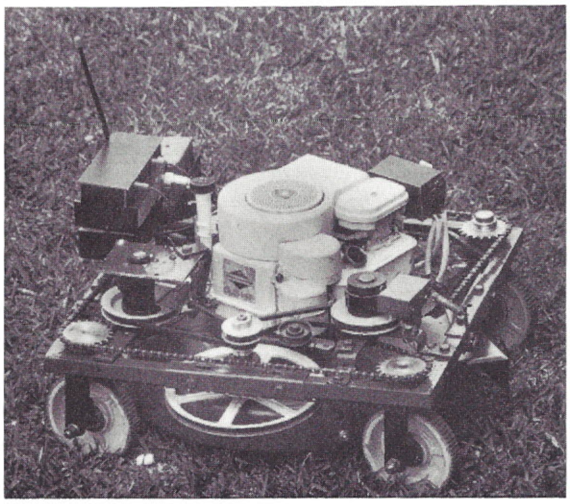

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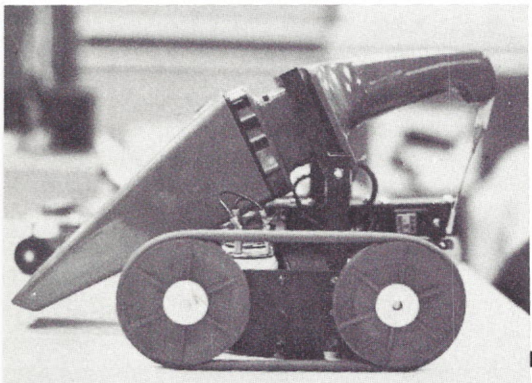

trol. In addition to the robots being demonstrated by Androbot, Heath, and RB, several Personal Robot Developers had flying, rolling, and crawling robots under remote control. The uncertainty of radio control interference particularly sprang to mind when everyone gathered around to see Reza Falamak demonstrate his EZ Mower, a radio-controlled lawn mower which won a prize as most useful robot. Although several comments were made about taking over the mower and heading it towards the neighbor's petunias, the machine danced flawlessly about the exhibition floor.
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One of the products which attracted much attention from both attendees and exhibitors was MENOS 1 from Virtual Devices, Inc. MENOS 1 is a HERO 1 emulator and software development system for the IBM and IBM-lookalike computers. The system allows you to simulate the motion of eight motors and eight sensors on the HERO 1. Once the software is ready for actual testing, it can be sent to the HERO 1 robot via RS-232 or radio link. MENOS 1 allows programmers to develop complex applications for the HERO 1 without having to continually enter data on the small hexadecimal keypad. The amount of interest this product generated was incredible. The question often arose if Virtual Devices was planning to introduce similar software for any of the other personal robots. Although there weren't any current plans, it is possible that versions for other machines might soon appear.

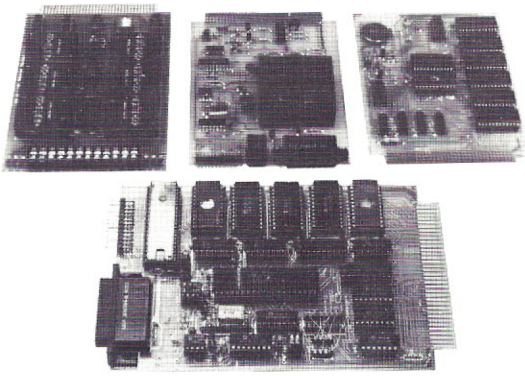
The Robotic Industries Association attended the show to support their recent move to allow personal robot manufacturers into the RIA. This move recognizes the personal, educational, and experimental manufacturers as serious businesses. The RIA is now in a position to transmit necessary information between two diverse groups, the small robot developer and the industrial robot manufacturers.

Other companies such as Micromation, Inc. and Spectron Instrument Corp. showed off their various robots and robot accessories. Remote Measurement Systems demonstrated its ADC-1 data acquisition and control system which can be connected to any computer with an RS-232 serial port. The inexpensive system can monitor any type of variable resistance sensor and track temperature, light, pressure, humidity, sound, etc. An optional BSR controller allows you to control lights and electrical appliances around the house.

The Personal Robot Developers had their machines floating and running about a special exhibit area. One machine, created by Brent DeWitt, floated about suspended by a bag of helium. Bill La's Fetal I and Fetal II demonstrated the maneuverability of a three-wheeled vehicle with special rollers. Other robots demonstrated how to put out fires or just have a good time wandering around the exhibits.

When the lights were finally dimmed Sunday night and the doors closed to the public, the exhibitors said goodbye to old and newly-made friends, packed up their equipment, took one last look around, and realized that the First International Personal Robot Congress had been a big success. In the back of everyone's minds were plans and hopes for the Second International Personal Robot Congress.

EMTROL'S SBC 828 MICRO CONTROLLER



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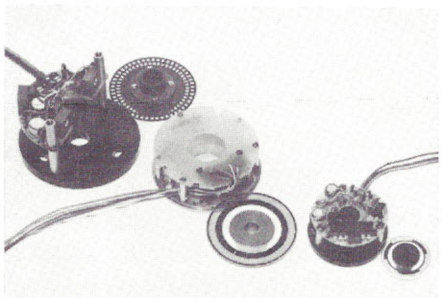

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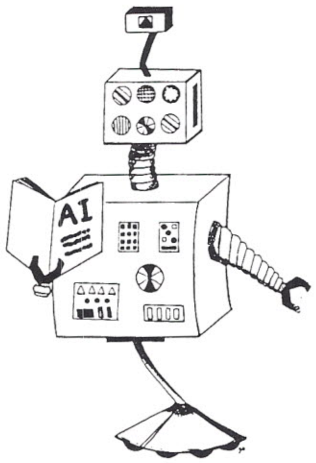

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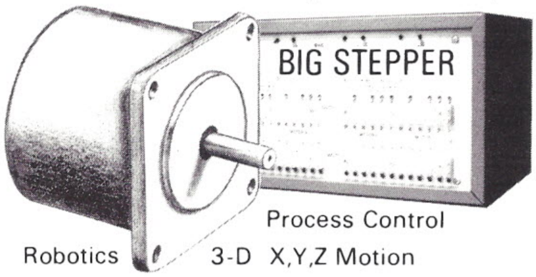

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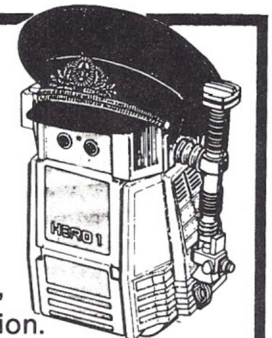

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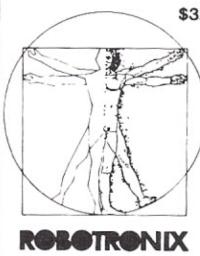

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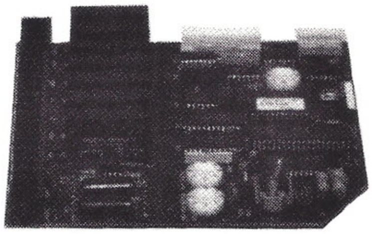
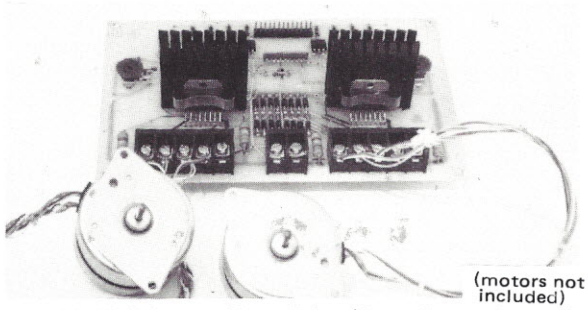


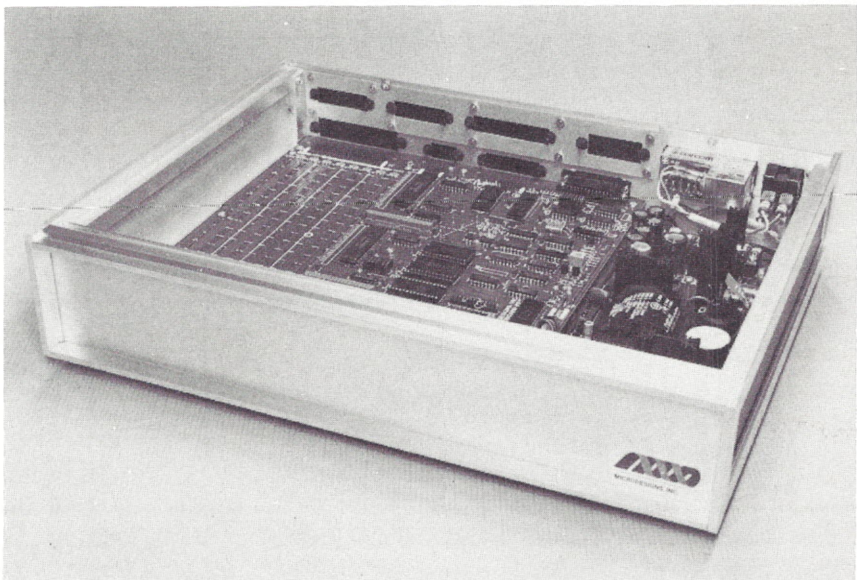


Motion Control Microcomputer

The Whedco Target M Series microcomputer is intended for motion and positioning control through the use of motors and associated interface devices. The Target can operate as a complete standalone computer, or as an intelligent peripheral to other control devices. It is also well-suited to act as an integral part of distributed processing applications where real-time control and information exchange are required.

The Target controls stepping and DC servomotors in any combination. It is ideal for controlling multiple axes in an asynchronous mode. Complete machine control can be implemented using devices such as encoders, LVDTs, and switches. Special software, such as velocity tracking and phase locked loop (PLL) can provide control of coordinated motion and reduce development time.

The Target conforms to Z80, STD Bus manufacturers' group specifications. Standard on all models is a central processor card containing two RS-232 ports with 19.2k bps communications, 12 Kbyte PROM memory of which 10 Kbytes contain the Target-Forth kernel, 2 Kbytes of programmable memory, and a Z-80A processor.



A parallel I/O board contains 21 control lines at 5 to 24 VDC operating in sink mode. Hardware options include an Intelligent Stepping Motor Controller, an Intelligent DC Servocontroller, Dual Channel Signal Processor, A/D Converter, D/A Converter. Software options include Phase Locked Loop Control, Velocity Tracking, Target-Forth for PC-DOS or CP/M operating systems, and a Z-80 to Target-Forth cross-compiler.

For more information, contact: Whedco, 6107 Jackson Rd, Ann Arbor, MI 48103, (313) 665-5473.

Circle 50

Real-Time Operating System for IBM PC

The PC/iRMX Operating System is an easy-to-use, comprehensive multiprogramming system. PR/iRMX extends the architecture of the underlying processor by providing a collection of new operations that act on the operating system objects provided by the system or user-created extensions. The multiprogramming environment, based on a real-time, event-driven scheduler, provides an efficient foundation for applications including process control, intelligent terminals, office systems, data communications, and medical electronics.

PC/iRMX includes facilities for executing programs concurrently, sharing resources and information, servicing asynchronous events, and interactively controlling system resources and utilities. The operating system also provides all major real-time facilities including priority-based system resource allocation, means for concurrently monitoring and controlling multiple external events, real-time clock control, interrupt management, and task dispatching. The PC/iRMX Operating System is composed of an object-oriented nucleus, device independent basic and extended I/O systems, terminal handler, bootstrap and application loaders, and a human interface with complete command line interpreter. Supported languages include Pascal, FORTRAN, PL/M, and a screen editor.

For more information, contact: Real-Time Computer Science Corp., PO Box 300-886, Camarillo, CA 93011, telephone (805) 482-0333.

Circle 51

HERO Ranging

Interface Technology has announced a Polaroid Rangefinder interface for the Heath ET-18 HERO robot. The package includes all necessary hardware and software for using the ultrasonic rangefinder including the ultrasonic transducer, the Polaroid driver and interface board housed in a plastic mounting case, and software routines for collecting the range data, converting it to inches, and displaying it on HERO's LED display. All distance timing is performed in software. The transducer has a range of 35 ft. and a resolution below a fraction of an inch.

The unit is available for an introductory price of $89, fully assembled and ready to install. It requires two input and one output bit at TTL levels. The demo software is for a Motorola 6800-family computer.

For more information, contact: Interface Technology, Inc., Box 745, College Park, MD 20740, (301)490-3609. Circle 52

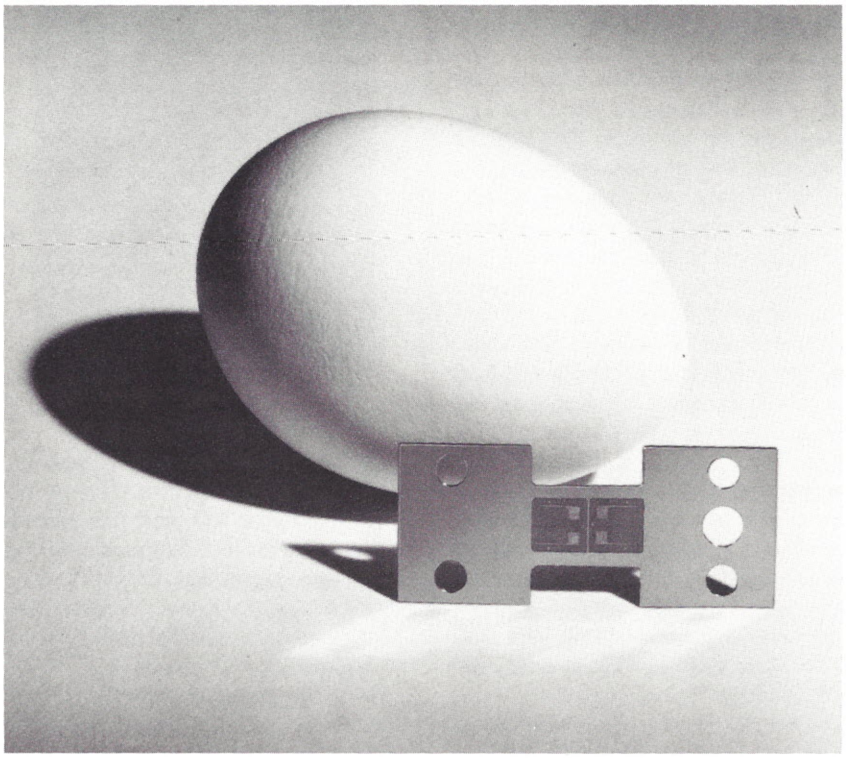
New Products

Force Translator

The Force Translator from Revere Corp. of America is a primary transducer for converting physical forces into meaningful electrical signals in applications as diverse as control instrumentation and bathroom scales. Detectable forces include tension, compression, torque, and pressure. By employing a Force Translator, in-product parameters like weight, level, and mechanical load (or overload) can be easily tracked and controlled.

Force Translator elements are available in a wide variety of ranges from 0-2 oz. to 0-100 lb. Revere will work closely with customers to develop and manufacture the specific sensor. Due to newly-developed production techniques, Force Translator elements are cost-effective in a broad range of applications.

Further information about the new Force Translator element is available from Revere Corporation of America, 845 North Colony Rd., PO Box 56, Wallingford, CT 06492, (203) 269-7701. Circle 53



SBC With Prototyping Area

Software-compatible with Intel's SBC-80/24 single-board computer, Microdesign's Multibox-85 is intended for stand-alone control or instrumentation applications. Prototyping area is provided on-board for customized circuitry, front panel switches, front panel LEDs, and rear panel connectors. Plated-through DIP pad patterns for up to 15, 16-pin IC equivalents as well as pads for a mixture of up to 13 switches and up to 35 LEDs are provided. The rear panel is prepunched for eight connectors in five commonly-used sizes. Complete with a 65W power supply operating from 115 VAC, the 3.5 in. high cabinet is available in desktop or 19 in. rackmount versions.

The 4.84 MHz, 8085A-2 processor operates with no memory wait states and can accommodate from 4 to 48 Kbytes of EPROM, and from 2 to 32 Kbytes of low-power CMOS programmable memory. All programmable memory data is maintained for a minimum of 10 days by a trickle-charged NiCad battery. Standard I/O includes a programmable RS-232 serial port with built-in DB-25 connector, 48 unbuffered parallel lines, and two SBX connectors, each of which can accommodate a dual-width Multimodule.

Priced at $1595 for the tabletop version, and $1620 for the rackmount version, Multibox-65 is available from stock to 60 days. The printed-circuit board, Multiboard-85, is available unpackaged for $895.

For additional information, contact: Mr. David R. Cornish, VP, Microdesigns, Inc, 1874 Forge St., Tucker, GA 30084, telephone (404) 493-6318. Circle 54

Varicalc Equation-Solving Software

Varicalc™ is a versatile program for the Apple II™ series microcomputer that interactively solves science, engineering, and business equations. Varicalc can simulate complex physical, chemical, and mathematical processes as well as accept real-time input directly into a predefined model.

Varicalc's most novel feature is the use of *variators* to change variables interactively. The variators can be two game paddles or a joystick, the left or right arrow keys, or an automated loop variator with selectable range and step size. The analog voltage from Interactive Microware's Adalab™ data acquisition interface card can also be used as a variator, and any variable can be used to control Adalab's analog voltage output. This permits feedback control of real-time processes according to complicated control equations.

Varicalc will solve for any one of 19 variables on the right or left side of a formula without rearranging the formula. Results can be plotted on the Apple computer's high-resolution graphics screen. Up to 255 equations may be stored on disk for quick retrieval.

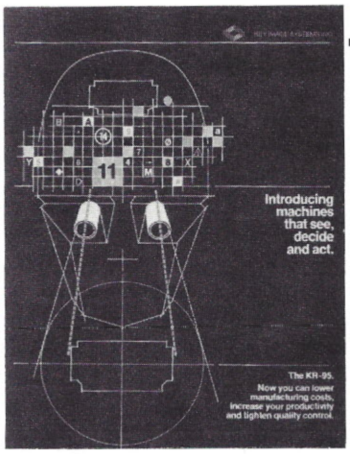
The Varicalc software is available for $100. The manual alone is available for $5.00, which is deductible from your software purchase. For further information, contact: Interactive Microware, PO Box 139, State College, PA 16804, telephone (814) 238-8294. Circle 55

Robot Justification Software

The RobotJustification program provides a sophisticated, but easy-to-use, spreadsheet for use on the IBM Personal Computer. This spreadsheet provides a detailed format for assembling and evaluating economic factors associated with the acquisition of an industrial robot. The program is unique, having been tailored for analyzing robot acquisition decisions based on an evaluation of applicable tax and depreciation benefits under the new Federal tax laws. The program calculates return on investment and payback period based on the applied data. The user supplies data such as robot and installation costs, while all of the analysis is calculated by the Robot-Justification program. A 70-page guide to the economics of justifying an industrial robot is also provided.

For more information about the Robot-Justification Software, which retails for $99.95, contact Technology Research Corp., 5716 Jonathan Mitchell Rd., Fairfax Station, VA 22039, telephone (703) 250-5136.

Circle 56



Vision Brochure

A variety of industrial vision system applications and the use of the KR-95 image recognition and inspection systems are described in a four-page brochure from Key Image Systems, Inc. The brochure illustrates reading alphanumeric characters on packages, tags, and labels, and monitoring bulk material for defects.

For a free brochure, write Key Image Systems, Inc., 20100 Plummer St, Chatsworth, CA 91311, telephone (818) 993-1911.

Circle 57

Real-Time Expert Systems

Optimum Technologies, Inc. has announced the Proteus-1 development tool for creating expert systems for intelligent instruments, defense equipment, robots, and machine tools. Proteus-1 is an offspring of applied expert systems research. A rule-based knowledge representation schema, forward/backward chaining, and weighted certainty/probability allows the system developer to produce quality expert systems capable of being placed in read-only memory.

Proteus-1 offers Optimus, a powerful stepwise approach for converting human expert's knowledge into Optima, a plain English language that links Proteus-1 with almost any microprocessor. Optima can be learned within three hours. The tool has two User's Guides, the Optima source code, and is available on an exclusive annual licensing basis for each product.

For more details, contact Optimum Technologies, Inc., 756 Foothill Rd, Big Flats, NY 14814, telephone (607) 562-3420.

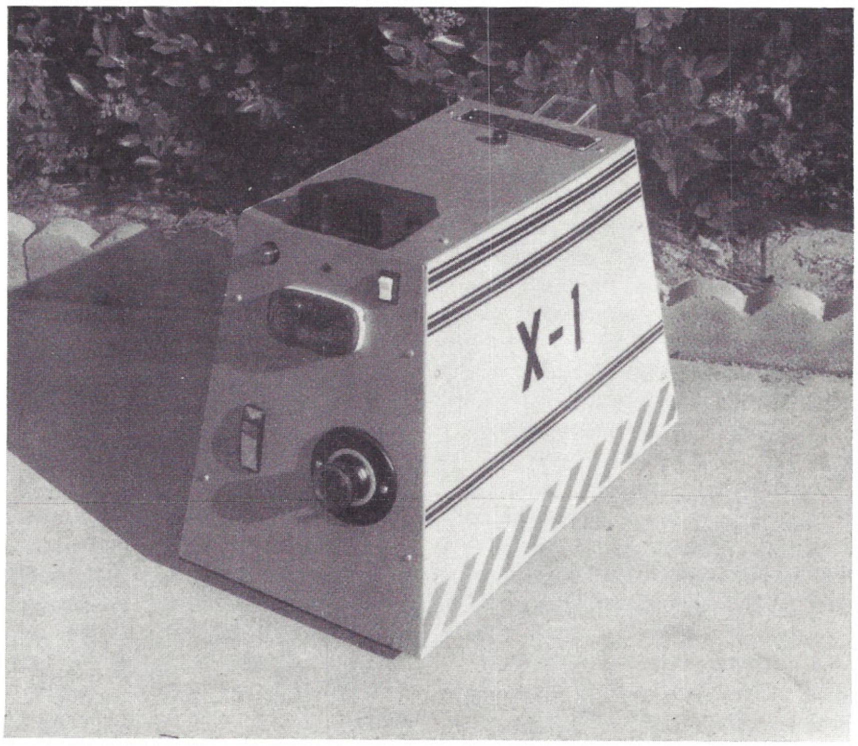
Circle 58

Utility Programs

Robot Shop has introduced four new utility capabilities for its line of Home Robot kits. The new capabilities expand the usefulness of Home Robots, to not just experimenters, but every household. The security guard routine detects human intruders, and sounds an alarm or activates the robot to harass intruders. The smoke and fire detection systems are sensitive to smoke and burning gases. The household air purification option silently and electronically cleans household air and removes odors, smoke, fumes, pollen, dust, bacteria, and viruses. The robot options also include an electronic pest control which drives away pests with powerful blasts of ultrasonic sound waves that are imperceptible to people and pets. The new capabilities add a practical side to the Home Robots.

The new utility options start at $19.95. For more information, contact the Robot Shop, PO Box 582, El Toro, CA 92630.

Circle 59



Continued from page 7

receiver and proportional control system. Slated for introduction this fall, the radio receivers are useful for people interested in developing their own remote-controlled robot devices. The proportional receivers are designed to fit inside scale model planes, cars, and buildings. As such, they are very small and do not draw a lot of power. The typical radio-controlled model on display was a small tractor trailer with two D cells in the trailer and the radio receiver inside the tractor. The controllers will be available in a variety of channels and configurations. I'll provide more information when the product is officially announced for delivery.

REAL-TIME FORTH

Forth, as many of you probably know, is a small, stack-oriented programming language which was originally designed for real-time, multitasking machine control. Although it has not grown into a major force in the world of computer languages, it has created a devoted following of programmers and designers. Forth devotees would have you believe that once you have used Forth, you will never go back to any other programming language.

Approximately 140 Forth devotees gathered at the *1984 Rochester Forth Applications Conference*. Various speakers discussed robot vehicles, music generation, state machines, multitasking, Forth computers, and telescope control. Forth was originally designed to control a telescope and the astronomical community is still very well represented.

One of the points brought home to me was the amount of real-time control work being done by astronomers. Although many of the control algorithms are not unusual, the degree to which the machinery is controlled is phenomenal. John Montgomery from the Steward Observatory discussed a Forth system he is using to automatically track observed objects through a multiple-mirror telescope. John is talking about rotating a multi-ton telescope, and the building which surrounds it, through 9 Angstrom steps. The problems, and their solutions, should be interesting to anyone with an interest in moving machinery.

A question which I was repeatedly asked at the conference was why more robot manufacturers did not use Forth to develop their control programs? Forth is its own operating system and can stand alone. Forth is small and relatively fast. It provides real-time, low-level computer control.

One of the reasons for Forth's lack of wide-ranging popularity in the robot world may be due to the lack of standards. Although standards committees have presented two standards over the years, most implementations have gone beyond the standards and added their own enhancements, making many programs nontransportable.

Another problem is that Forth is a *different* language. Once you have learned a language such as BASIC, FORTRAN, C, or Pascal, it requires a serious effort to change programming styles to a Forth-like language. However, the results may be well worth the effort. Program designers concerned with space restrictions would do well to realize that fully-functioning Forth applications can be operated in as little as 4 Kbytes of memory. Development systems are often as small as 16 Kbytes.

Two products which have emerged during the last year may finally introduce Forth as a serious design tool for more programmers. Rockwell International introduced the R65F11, a modified 6502 designed specifically to run Forth. A complete development system consists of the R65F11, a read-only memory chip, a programmable memory chip, and an RS-232 interface. Companies such as New Micros, Inc. have already produced small, simple, Forth development and control boards using the chip.

The second product is part of National Semiconductor's Macromodule™ computer construction line. Macromodules are little black boxes which plug into each other ad infinitum. A set of pins on the bottom of each box plugs into the socket on the top of another box. Each box is a functional unit. One contains a CMOS Z80, a monitor program, and some programmable memory. Other boxes contain 16 Kbytes of programmable memory, a direct-connect modem, RS-232 serial interface, analog-to-digital or digital-to-analog converters, and TTL control ports.

At the Rochester conference, National Semiconductor was showing their Forth module. This module plugs into the computer system just like any of the other stackable components. It provides a full Forth development system with multitasking capabilities. Since the modules do not presently have a little black box for disk control (although one is promised) the Forth programs are edited by decompiling the programs into programmable memory, editing them, and then recompiling. This system appears to be very fast and reliable since the CMOS programmable memory has a memory backup. Conversely, programs could be transmitted and received over an RS-232 communications port.

The introduction of the Rockwell and National Semiconductor parts opens a world of rapid program and system development. These products, and the systems which use them, could open the world of Forth programming to a wider audience. In the meantime, I would be like to hear from people using Forth for robot control, either industrial, personal, or experimental.

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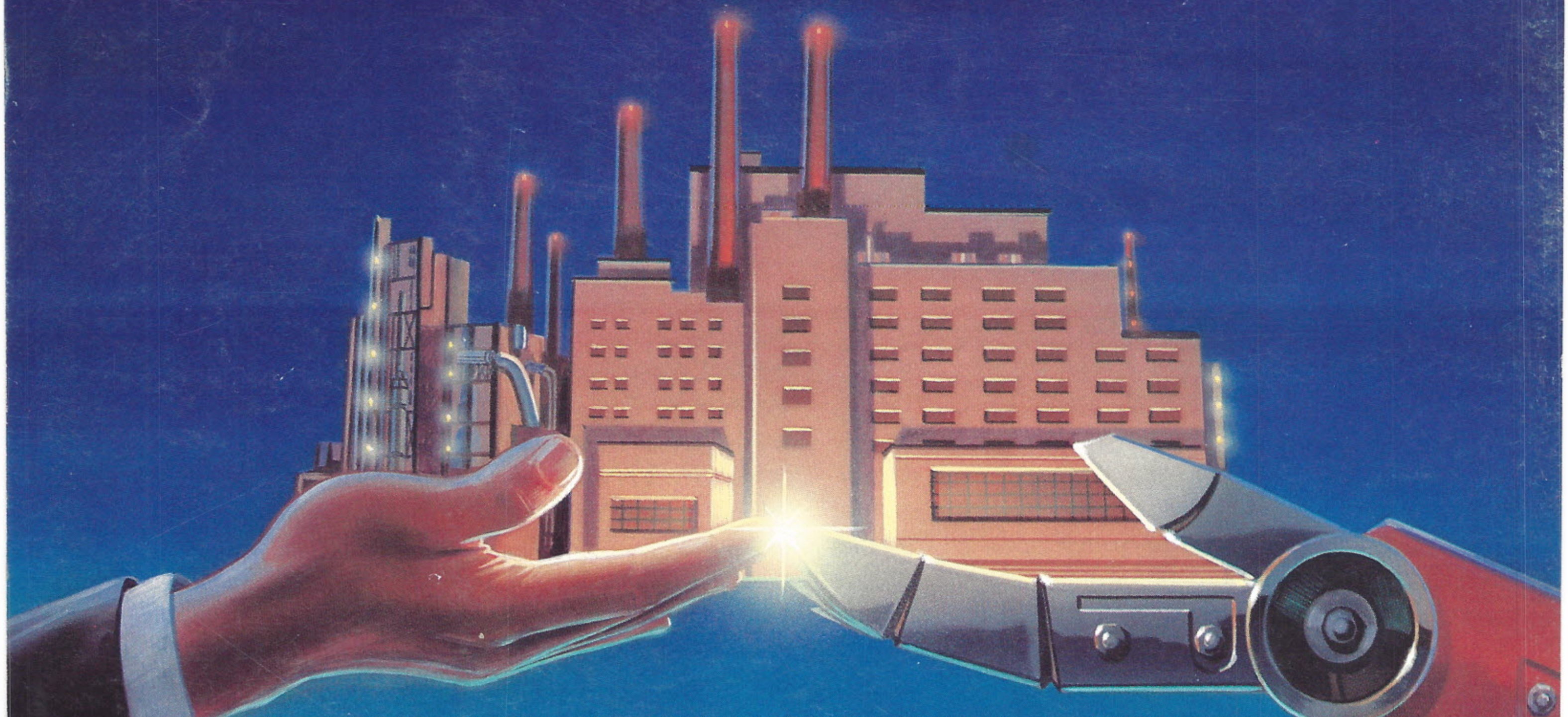

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